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EFFECTS OF LIVESTOCK PASTURING ON NONPOINT SURFACE RUNOFF

by

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This project was initiated to evaluate the effects of livestock pasturing in the humid regions of the United States on the quality of nonpoint surface runoff. Three pasturing regimes which are more commonly practiced in the corn belt states were evaluated to determine their potential contribution to nonpoint source pollution. This information is useful in determining optimal practices which will lead to the development of Best Management Practices (BMPs).

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FOREWORD

EPA is charged by Congress to protect the Nation's land, air and water systems. Under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise, and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life. In partial response to these mandates, the Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma is charged with the mission to manage research programs to investigate the nature, transport, fate, and management of pollutants in groundwater and to develop and demonstrate technologies for treating wastewaters with soils and other natural systems; for controlling pollution from irrigated crop and animal production agricultural activities; for controlling pollution from petroleum refining and petrochemical industries; and for managing pollution resulting from combinations of industrial/industrial and industrial/municipal wastewaters.

This project was initiated to evaluate the effects of livestock pasturing in the humid regions of the United States on the quality of nonpoint surface runoff. Three pasturing regimes which are more commonly practiced in the corn belt states were evaluated to determine their potential contribution to nonpoint source pollution. This information is useful in determining optimal practices which will lead to the development of Best Management Practices (BMPs).

Clinton W. Hall

Clinton W. Hall, Director
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ABSTRACT

This research program was initiated with the overall objective of evaluating the effects of livestock pasturing in the humid regions in the United States on the quality of nonpoint surface runoff. Specific objectives were to establish the contribution of pollutants from nonpoint source pasturing regimes, to establish what happens to hydrologic and water quality parameters in nonpoint surface runoff from pastures and to identify pasture management practices that affect nonpoint source pollution.

Three pasturing regimes were monitored and evaluated: summer rotational grazing and winter feeding of hay on one pasture, summer rotational grazing with no livestock on pastures in the winter and winter rotational grazing of autumn regrowth with feeding of field stored hay.

Winter pasturing and feeding of hay caused a marked increase in the number of runoff events and the volume of runoff as compared to previous meadow practices and to summer pasturing only. Dormant (Nov-Apr) season nutrient fluxes were greater than those in the growing (May-Oct) season. Analysis of the soluble and sediment fraction of the runoff samples indicated that the nutrients were principally in the soluble phase.

Analysis of discrete sample data collected throughout a runoff event indicated that nutrient transport was essentially matched with runoff, i.e. a linear relation can be assumed between runoff volume and nutrient delivery. In general, soluble nutrient concentrations are a function of hydrologic variables, e.g. precipitation, rainfall intensity and antecedent soil moisture; whereas, sediment related nutrient concentrations were affected by pasture management practices.

Microbiological analyses for total coliform, fecal coliform and fecal streptococci were conducted. The number of bacteria exceeded water quality criteria for pasture runoff. The ratio of fecal coliform to fecal streptococci did not clearly indicate whether the fecal source was cattle or wildlife. The number of bacteria in a sample collected early in a storm event was similar to a sample collected near the end of the event.

This report was submitted in fulfillment of Grant No. R-804631 by The Ohio Agricultural Research and Development Center under the sponsorship of the U. S. Environmental Protection Agency. This report covers the period November 1, 1976 to March 15, 1980 and work was completed as of August 30, 1980.

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LIST OF ABBREVIATIONS AND SYMBOLS

BMPs	-- best management practice(s)
BOD	-- five-day biochemical oxygen demand
CI	-- confidence interval
cm	-- centimeter
CN	-- curve number
COD	-- chemical oxygen demand
COVER	-- computer variable for percent cover or vegetation
DS	-- dormant season (November-April)
ED	-- early delivery
FC	-- fecal coliform
FS	-- fecal streptococci
GS	-- growing season (May-October)
ha	-- hectare
I	-- intensity factor for precipitation
K	-- potassium
Kg/ha	-- kilograms per hectare
LD	-- late delivery
M	-- antecedent top soil moisture
MD	-- matched delivery
mg/ℓ	-- milligrams per liter
min N	-- mineral nitrogen ($NH_3 + NO_2 + NO_3$)
mm	-- millimeter
N	-- nitrogen
NAEWS	-- North Appalachian Experimental Watershed, Coshocton, Ohio
NH_3	-- ammonia
NO_2	-- nitrite
NO_3	-- nitrate
NLIN	-- computer programming routine from the Statistical Analysis System (SAS)
NT	-- computer variable used in SAS program for calculating CI
OARDC	-- Ohio Agricultural Research and Development Center, Wooster, Ohio
OCN	-- optimized curve number
ΔOCN	-- change in optimized curve number
ON/OFF	-- computer variable for cattle on or off the pasture
org N	-- organic nitrogen
P	-- phosphorus; amount of precipitation or storm rainfall
PRECIP	-- computer variable for precipitation
Q	-- volume or quantity of storm runoff
RAINT	-- computer variable for precipitation intensity factor
r^2	-- coefficient of determination
S	-- soil moisture
SS	-- an objective function used to optimize curve numbers

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SAS -- Statistical Analysis System (Barr et al., 1976)

SEA-ARS -- Science and Education Administration, Agricultural Research Service

Sed K -- sediment potassium

Sed N -- sediment nitrogen

Sed P -- sediment phosphorus

SOILM -- computer variable for antecedent soil moisture

Sol K -- potassium in solution, not with sediment

Sol N -- nitrogen in solution, not with sediment

Sol P -- phosphorus in solution, not with sediment

TC -- total coliform

TIME/O -- computer variable for time factor from when cattle went on or came off pasture

TOC -- total organic carbon

Tot N -- total nitrogen

Tot P -- total phosphorus

USDA -- United States Department of Agriculture

$\bar{x}$ -- arithmetic mean (average)

WHSED -- computer variable for sediment flux

WS -- watershed

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SECTION 1

INTRODUCTION

Livestock production systems utilizing pastureland are one segment of agricultural production for which the extent of nonpoint source pollution has not been clearly defined, and for which Best Management Practices (BMPs) need to be designed. Beef cow and calf production is increasing in East Central United States, a region extending from Pennsylvania, West Virginia and Virginia across Ohio and Kentucky to Iowa and Missouri. Currently, this area has about ten million head of beef cattle. Many of the cattle in this area are raised on small farming operations. For example, about 2/3 of the 1.4 million cattle raised in Ohio are on farms with 20-99 head (Census of Agriculture, 1974). Typically, most livestock in this region are pastured during the summer. In winter, the livestock may be fed in the barn or on an open lot, fed hay out on pasture or kept on winter pasture of autumn-saved regrowth and field stored hay. The land used for such production is primarily rough, hilly land that is susceptible to erosion if cultivated or otherwise handled so that the vegetative cover is lost and the soil exposed. This land, in permanent pasture, represents a large, important part of the region.

This study was conducted during 1977-1980 by the Ohio Agricultural Research and Development Center (OARDC), Wooster, Ohio and the United States Department of Agriculture, Science and Education Administration, Agricultural Research Service (USDA SEA-ARS) at the North Appalachian Experimental Watershed (NAEW) near Coshocton, Ohio. Long-term hydrologic records from experimental watersheds (WS) at NAEW provided background for this study. Three pasturing regimes were monitored: summer rotational grazing and winter feeding of hay on one of the pastures (WS 129 monitored), summer rotational grazing with no winter feeding on pastures (WS 110 monitored), winter rotational grazing of autumn regrowth and feeding of field stored hay (WS 106 monitored).

This report is a presentation of the results obtained from a research study with the following threefold objective: (1) establish the contribution of pollutants from nonpoint source pasturing regimes, (2) evaluate changes due to livestock pasturing in the hydrologic and water quality parameters in nonpoint surface runoff and (3) identify pasture management practices that affect nonpoint source pollution.

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SECTION 2

CONCLUSIONS

Evaluation of three pasture regimes indicated that winter pasturing increased the surface runoff. Where winter feeding of cattle on one watershed (WS 129) occurred, the runoff volume was threefold that of a predicted volume based on 23 years of previous hydrologic record. Winter rotational grazing and feeding of field stored hay (WS 106) increased the runoff by 75% over that predicted. Summer rotational grazing only (WS 110) increased the observed runoff by 17% over that predicted. The increased runoff volumes were primarily associated with the dormant season, winter feeding and pasturing.

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Average dormant season (DS), November through April, nutrient fluxes were greater than those in the growing season (GS), May through October for all three pasturing regimes. The flux of total potassium (Tot K), 143 kg/ha, during the study period was larger than total nitrogen (Tot N) or phosphorus (Tot P), 73 and 14 kg/ha respectively. The flux of sediment nitrogen (Sed N) was larger than sediment potassium (Sed K) or sediment phosphorus (Sed P) by a factor of three to six. The sediment to soluble flux ration was largest for phosphorus (P) and least for potassium (K), so that P transport is more associated with sediment than either nitrogen (N) or K. A comparison of nutrient fluxes from the control watershed with the pasture watersheds showed that N and K were two to ten times larger and that P flux was larger by three to ten orders of magnitude for pasture watersheds.

Periodic samplers were utilized to partition runoff samples during each storm and the discrete samples were analyzed separately. Normalized flux scatter plots indicated that N and K tended toward early delivery as related to runoff volume. Phosphorus tended toward late delivery. Analysis of the nutrient flux plots, using 90% confidence intervals, indicated that nutrient delivery was essentially matched with runoff, i.e. a linear relation can be assumed between runoff volume and nutrient delivery.

Linear regression was used to identify variables that contribute to nutrient flux in runoff. In general, soluble nutrient concentrations are a function of hydrologic variables such as precipitation, rainfall intensity and antecedent soil moisture; whereas, sediment related nutrient concentrations were affected by pasture management, specifically cattle occupancy and time of occupancy.

The pasture management regimes are related to water quality in surface runoff in the following order with the first practice causing the least flux of nutrients: (1) summer rotational pasturing only, (2) winter rotational

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pasturing on autumn regrowth and field stored hay and (3) summer rotational pasturing and winter feeding with hay brought to the cattle on one watershed.

Microbiological analyses for total coliform (TC), fecal coliform (FC) and fecal streptococci (FS) confirmed previous studies that water quality criteria for coliform in runoff from pastures were exceeded. Ratios of FC to FS for pastured watersheds and a non-pastured, forested control varied to the extent that the source, either cattle or wildlife, of fecal material was not evident. Analyses showed little difference in the number of bacteria in runoff water collected early in a storm event with water collected near the end of a storm event. Therefore, bacteriological water quality criteria may be inappropriate for characterizing pasture runoff.

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SECTION 3

RECOMMENDATIONS

This report has established the contribution of nutrients and pollutants from nonpoint source pasturing regimes in the cool, humid region of East Central United States. Three years of detailed hydrologic data, water quality data and livestock-pasture management data have been collected. The nutrient transport was principally in the soluble form versus the sediment form and more occurred during the DS than during the GS. A marked increase in the volume of runoff occurred during the DS due to livestock pasturing. These results support the following recommendations:

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1. Watershed modeling efforts should include the impact of livestock pasturing on hydrology, nutrient flux and pollutant transport.

2. Composite, proportional samples of runoff can be used to measure nutrient flux from meadow and pastured watersheds.

3. Alternative winter (or DS) livestock management practices need to be evaluated in order to identify BMPs for winter pasturing.

4. Identify and evaluate fertilization practices that would reduce flux of nutrients in runoff water, e.g. use legume-grass pasture in lieu of using chemical nitrogen fertilizer.

5. Bacteriological water quality criteria should not be used as a principal parameter to identify sources of nonpoint pollution.

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SECTION 4

EXPERIMENTAL FACILITIES

A "memorandum of understanding" between the OARDC and the USDA SEA-ARS, NAEW enables the two institutions to conduct cooperative research. All the watersheds at NAEW have a hydrologic history of more than 30 years. As part of a cooperative research effort between OARDC and NAEW, cattle pasturing programs were initiated in 1974 on areas B, D and E (Figure 1) containing small experimental watersheds. Figure 1 is a location map of the small watersheds at NAEW.

In 1977, additional runoff monitoring equipment was installed on three watersheds used in the cattle monitoring programs to obtain periodic monitoring of runoff. Runoff samples were analyzed for Tot N, mineral N (Min N) which includes ammonia (NH_3), nitrite (NO_2) and nitrate (NO_3), Tot P in solution and in sediment, Tot K in solution and in sediment, total organic carbon (TOC) and chemical oxygen demand (COD). Periodically, samples were analyzed for the number of total coliform (TC), fecal coliform (FC) and fecal streptococci (FS) bacteria.

PASTURES AND RESEARCH WATERSHEDS

Three pasture regimes are identified in Figure 1 as areas B, D and E. Within each of these pasture areas one watershed was monitored for runoff; in area B it was WS 129, in area D it was WS 110 and in area E it was WS 106. A forested watershed (WS 172) was monitored as a control.

The pasturing regimes, the fertilization programs and watershed characteristics for the research watersheds were as follow:

Area B (Figure 2). Summer rotational grazing (May-Oct) in pasture B1-B4 was done with 25 Charolais beef cows with calves. The total area in B was 17.2 ha. The area of B1, the researched pasture, was 3.1 ha. Cattle were wintered (Nov-Apr) in B1 with hay (square bales) brought to them. The hay was randomly placed in the pasture throughout the winter. Within pasture B1 was a gaged watershed (WS 129) of 1.1 ha. WS 129 consisted of Berks shaley silt loam with 18-25% slope and Rayne silt loam with 12-18% slope. The area was used as a meadow or a light summer rotational pasture from 1940 to 1975 when the present pasture regime was started.

Area B was seeded to orchard grass and was maintained with a moderate level of fertility using 56 kg N/ha in the spring and a maintenance level of available soil P and K at 28 and 168 kg/ha, respectively, Approximately

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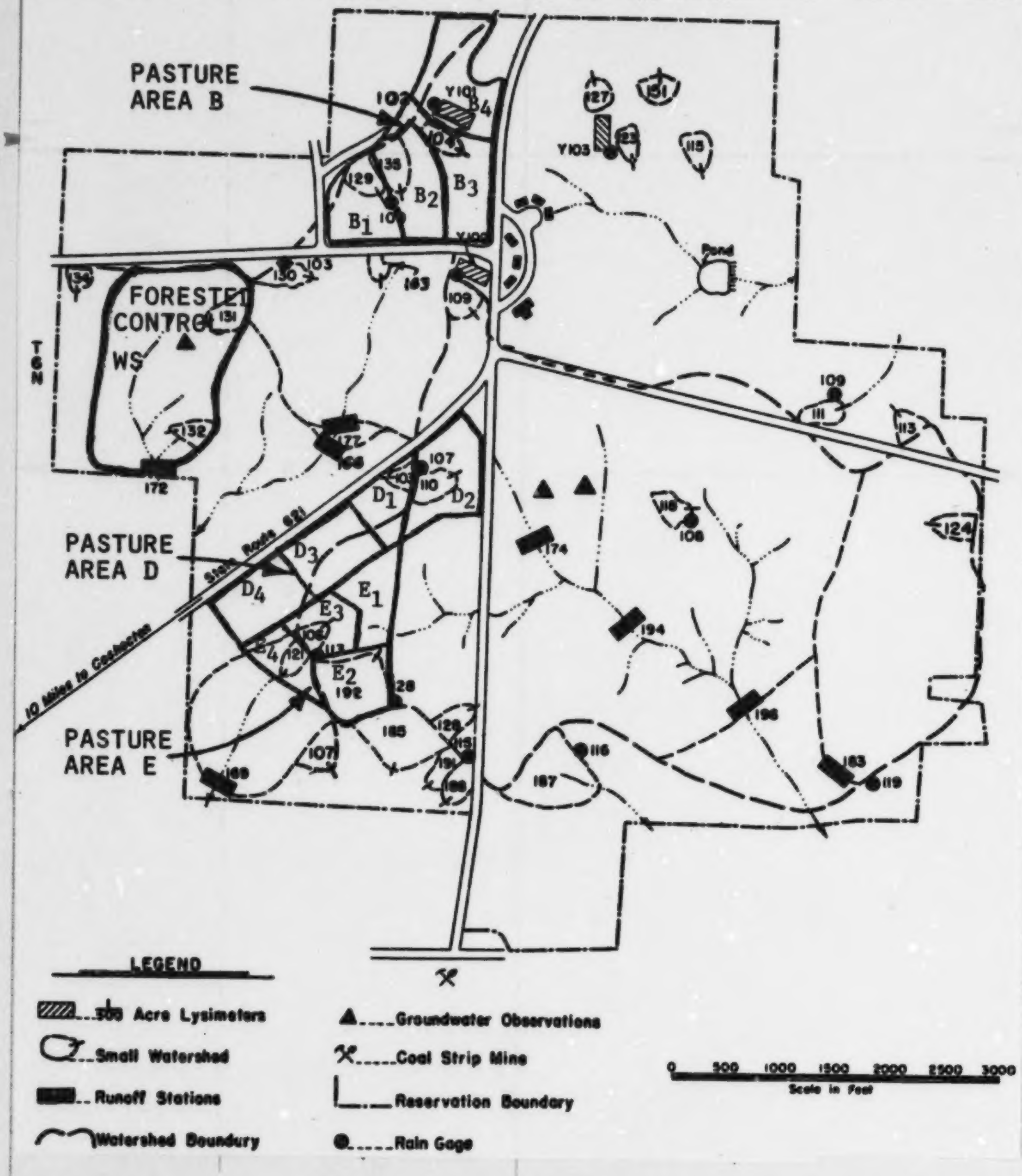

Figure 1. Location map of small watershed and pasture area B, D and E at the North Appalachian Experimental Watershed, Coshocton, Ohio.

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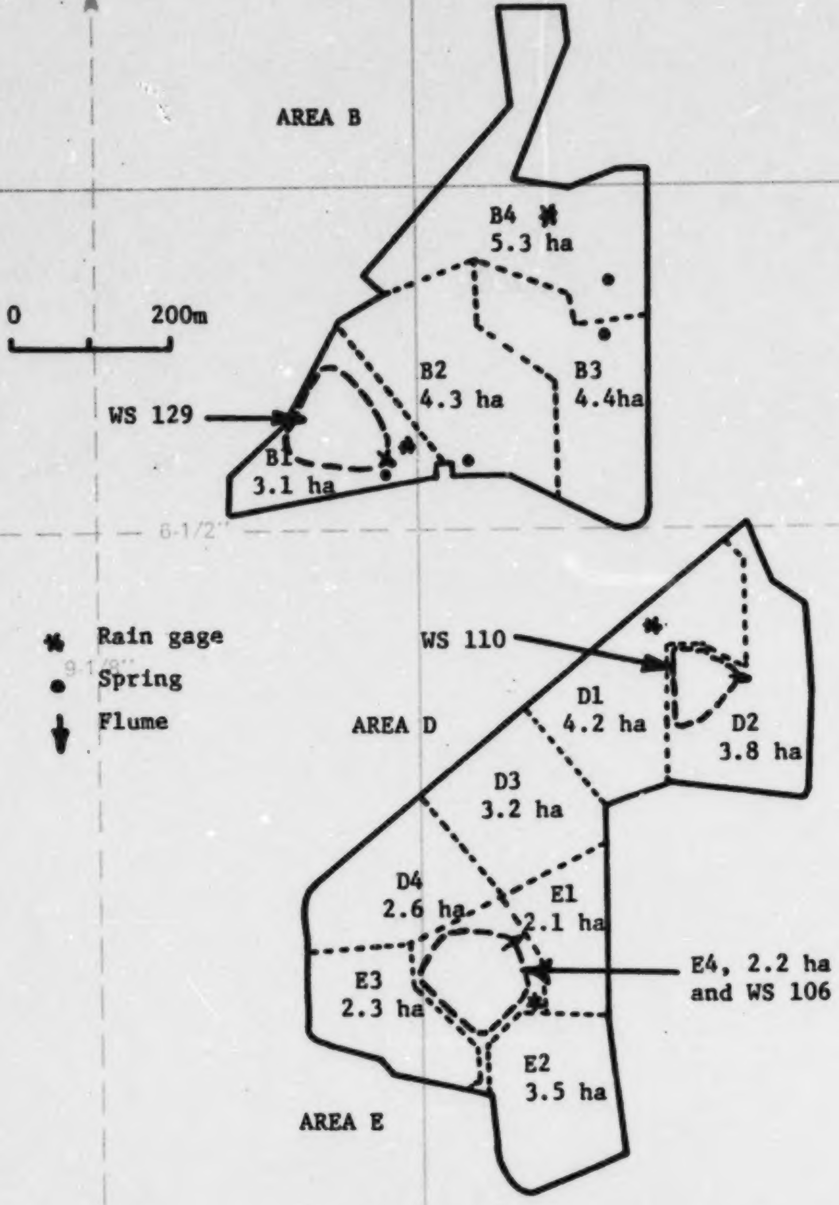

Figure 2. Diagram of pasture areas B, D and E and research watersheds 106, 110 and 129.

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290 kg N/ha was introduced in the hay fed to the cattle during the winter. Approximately 75% of the hay N will be in the cattle manure, which far exceeds the annual application of ammonium nitrate. Soil pH was maintained at 6.0 to 6.5.

Area D. Summer rotational grazing in pastures D1-D4 (no winter feeding) was done with 40 Charolais cows with calves. The total area in D was 13.8 ha. The pasture D2 has 3.8 ha and contained the research watershed, WS 110 of 0.86 ha. WS 110 consisted of Rayne silt loam with 2-6% and 12-18% slope and Keene silt loam with 6-12% slope. A seep is located above the flume. The area was maintained in a four-year rotation, corn-wheat-meadow-meadow from 1942 to 1975.

Area D was seeded to orchard grass. A high level of fertility was provided with an annual application of 224 kg N/ha (in three applications) and maintenance of soil P and K at levels of 56 and 336 kg/ha, respectively. Soil pH was maintained at 6.5 to 7.0.

Area E (Figure 2). Winter rotational grazing of fall regrowth and feeding of field-stored hay (large round bales) was done with 40 Charolais cows (those from area D). The total area in E was 10.1 ha. The pasture E3 has 2.2 ha and contained the research watershed, WS 106 of 0.63 ha. The area was seeded to tall fescue and the high fertility, as in Area D, was provided here.

Control watershed (Figure 1). A forested watershed, WS 172, was monitored to give data for comparison as a control. WS 172 has 17.6 ha of DeKalb channery silt loam, Berks shaley silt loam and Coshocton Rayne silt loam.

Pasture management practices, including fertilization, condition of vegetation, mowing and cattle occupancy were recorded in a farm operations log.

PRECIPITATION, RUNOFF AND RELATED MEASUREMENTS

Precipitation was measured using weighing rain gages that provided a continuous time record of rainfall. The rain gages were unshielded and the data were not adjusted for wind. A rain gage was located adjacent to each research watershed. Rain gages 100, 107 and 113 correspond to WS 129, WS 110 and WS 106, respectively (Figure 2).

Runoff was measured using recording H-flumes at the outlet of each research watershed. A calibrated stage recorder with a continuous timer recorded flow. The flume and stage recorder housing for WS 129 are shown in Figure 3. A close-up of the H-flume outlet is shown in Figure 4.

The offset Coshocton wheel sampler, Figure 4, separated proportional samples from the runoff flow. The separated samples were conveyed to an insulated, refrigerated storage (Figure 3). Figure 5 shows the device for collecting a series of 5 liter samples in the refrigerated storage. There were 14 buckets and an overflow drum which allowed for 15 samples in a sufficiently large runoff event. Runoff from the control watershed (WS 172) was collected in a composite sample for each event.

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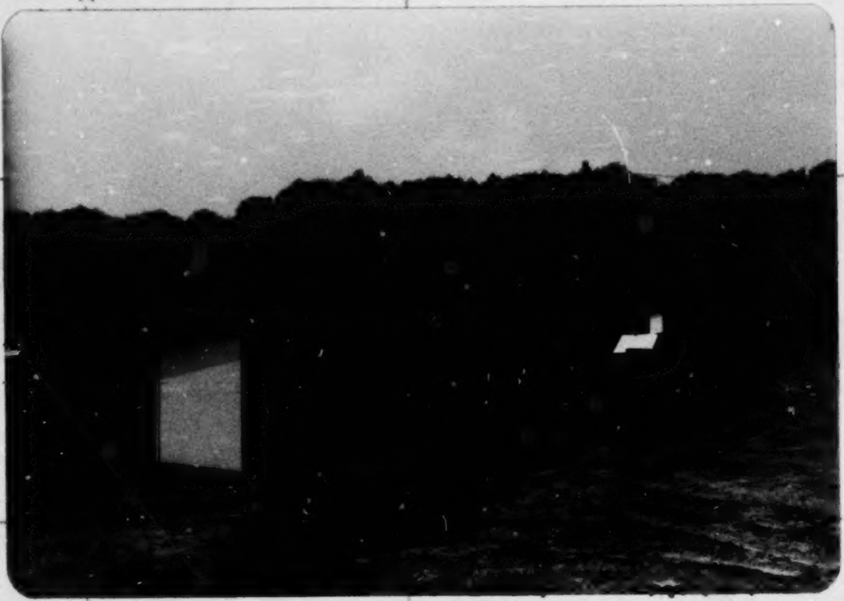

Figure 3. Watershed 129 with flume and stage recorder. Proportional sample is piped to insulated, refrigerated sample storage building.

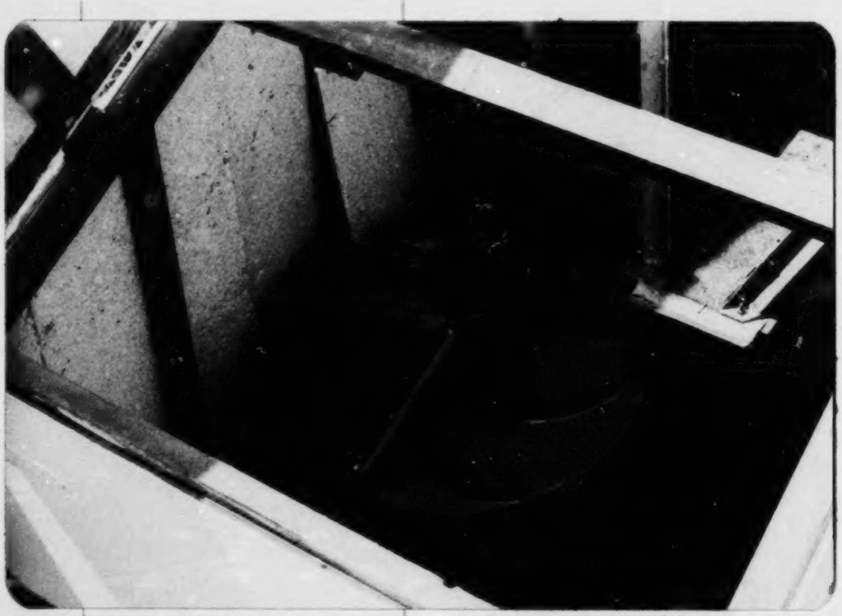

Figure 4. Close-up of H-flume outlet and offset Coshocton wheel sampler.

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Figure 5. Periodic (discrete) samples within refrigerated storage.

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Soil moisture data were obtained on a biweekly basis. Moisture in the surface soil profile was measured by gravimetric analysis. Moisture in the 20 to 120 cm profile was measured using a neutron probe.

Percent vegetative cover was obtained biweekly during the growing season of the study period.

SAMPLE ANALYSIS AND DATA TABULATION

The periodic runoff samples were analyzed for Tot N by a modification of the automated cadmium reduction procedure following sample digestion (Schuman et al., 1973). Samples were analyzed for ammonium nitrogen (NH_4-N) by an automated phenate method and for nitrite/nitrate nitrogen (NO_2/NO_3-N) by an automated cadmium reduction method (USEPA, 1974). Organic N was obtained by the difference between Tot N and Min N (the sum of NH_4-, NO_3- and NO_2-N).

A portion of the periodic runoff samples was composited to give enough volume to separate a sediment sample for analysis. The sediment samples were analyzed for Tot N.

Total P was determined by colorimetry after the samples were treated with concentrated acid. The modified phosphomolybate procedure of Yoe (1928 was used for liquid samples, while the procedures of Murphy and Riley (1962) were used for Sed P.

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Flame photometry was used to determine the concentration of K in liquid samples. An ammonium acetate extraction procedure was used to obtain Sed K (Stamper, 1980).

The COD and the TOC of the periodic runoff samples were determined using the procedure outlined in USEPA, 1974.

The precipitation, runoff and chemical data were tabulated on the basis of growing season (May-Oct), the dormant season (Nov-Apr) and the total water year (May-Apr). The flux or transport of each chemical for a season is the sum of the fluxes for all runoff events.

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SECTION 5

RESULTS AND DISCUSSION

Data will be presented under the topics of precipitation, livestock management, hydrology, nutrient chemistry and microbiology. Each of these topics is interrelated and a final section will summarize their interrelation.

PRECIPITATION

The precipitation summary for the period of this study, May, 1977-March, 1980 is given in Table 1 along with the long-term mean monthly precipitation. Appendix A gives a graphical representation of individual precipitation events and associated runoff events. The average precipitation for the dormant season during this study was only 4% less than the long-term mean. The average precipitation for the growing season during this study was 25% greater than the long-term mean. The growing seasons in 1978 and 1979 were much wetter than normal.

The monthly precipitation values were compared to the long-term precipitation values (Table 1) and a double mass plot was developed (Figure 6). The double mass plot relates the accumulated monthly rainfall during the study period with the accumulated long-term mean monthly precipitation. If the data plot on or parallel to the 45° dotted line, then the precipitation for that period was similar to the average precipitation.

Dormant season (DS) 1979-80 was drier than normal, while DS 1977-78 and 1978-79 had more precipitation than normal during the middle of the season (Figure 6). The curve for the 1977 growing season (GS) indicates that it was dry in May and June while GS 1978 and 1979 were much wetter, particularly in August and September. It would be expected that during periods of below average precipitation less runoff would occur and during periods of above average precipitation proportionately more runoff, as well as runoff events, would occur.

LIVESTOCK MANAGEMENT

Forty cows were wintered in Area E and rotated through E1 to E4, normally spending about one month or more in each pasture. The periods when the cattle were on E3 (WS 106) are listed in Appendix B. Cattle were maintained on a pasture until the fall regrowth and the field stored hay were consumed.

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TABLE 1. MONTHLY PRECIPITATION DATA AT NAEW, COSHOCTON, OHIO FOR MAY 1977-APRIL 1980

Period	Precipitation				
	cm				
		1977-78	1978-79	1979-80	Long-term mean
Nov	--	9.09	3.73	6.17	6.32
Dec	--	9.35	10.72	4.19	6.25
Jan	--	7.85	9.63	4.09	6.91
Feb	--	0.89	6.17	1.73	5.56
Mar	--	6.02	4.67	12.75	9.09
Apr	--	7.90	11.56	7.42	8.92
Dormant Season	--	41.10	46.48	36.35	43.05
	1977	1978	1979	--	Long-term mean
May	2.54	10.87	11.25	--	9.58
Jun	4.67	16.66	9.92	--	10.67
Jul	17.55	4.37	12.75	--	11.15
Aug	7.19	15.29	17.75	--	7.90
Sep	17.20	7.01	17.75	--	7.29
Oct	7.11	12.50	4.22	--	5.84
Growing Season	56.26	66.70	73.64	--	52.43
Annual (Water year)	83.64	107.80	120.12	--	95.48

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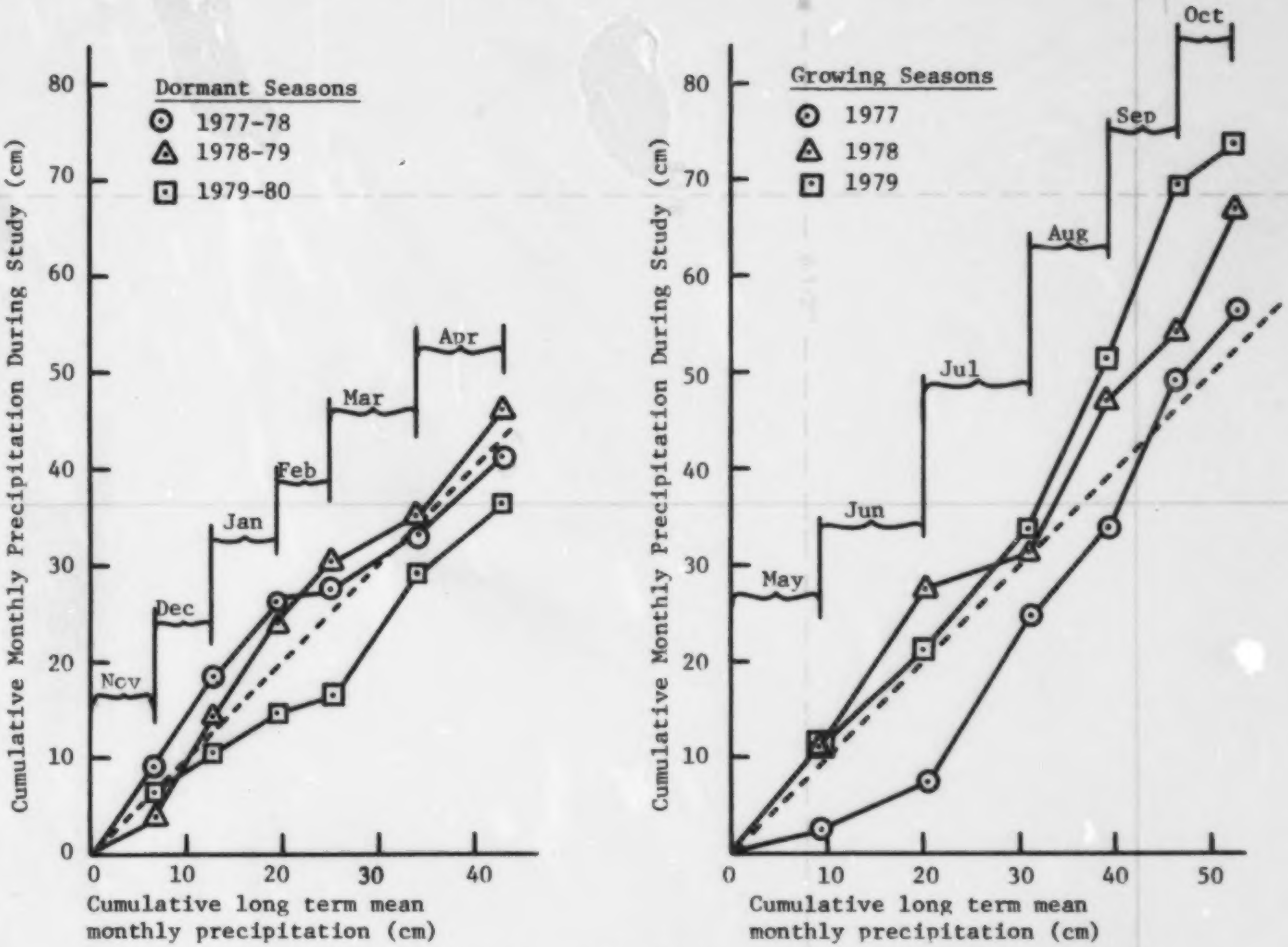

Figure 6. Double mass plots of accumulated monthly precipitation.

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The forty cows in Area E calved in March and were moved to Area D for summer rotational grazing. The cows and calves were rotated to a new pasture in Area D when the grass was grazed off. The period that animals were on D2 (WS 110) varied from one day to eight days with a mean time of 4.5 days (Appendix B).

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Twenty-five cows were maintained in Area B. During the summer they were rotated in B1 through B4. They averaged about seven days in Area B1 (WS 129) in the rotation. During dormant season, the cows were fed hay in Area B1 for 166 to 182 days (Appendix B).

HYDROLOGY

The effects of livestock pasturing on the hydrology of Area B, which includes WS 129, for the two years preceding this study were reported by Van Keuren et al. (1979). They reported that the runoff volumes on B2, B3 and B4 used only for rotational summer grazing were generally less than previously when the fields were in meadow and light pasturing. However, the runoff from B1 (WS 129), the area where cattle were fed throughout the winter as well as summer pasturing, was markedly increased. Also, the sediment transport from B1 increased while there was very little from B2, B3 and B4.

Runoff Prediction Equation

Using linear regression, Van Keuren et al. (1979) developed and verified a predictive equation for runoff volumes in terms of precipitation, a precipitation intensity factor and antecedent soil moisture. They used 23 years of data when WS 129 was in meadow or light pasturing preceding the present pasturing regime. The following analysis was conducted in the same manner.

Using the stepwise regression procedure in the Statistical Analysis System (SAS) computer package, Barr et al., (1976), runoff predictive equations of the following form with the coefficients listed in Table 2 were developed for WS 106, WS 110 and WS 129.

$$Q_p = x + aP = bI = cM + dPP + ePI + fPM + gMI$$

Where Q_p is the predicted runoff (depth in mm over WS) for an event, the P, I and M terms are precipitation amount, precipitation intensity factor (amount falling at an intensity greater than 25.4 mm/hr) and antecedent top soil moisture, all in mm; and the PP, PI, PM and MI terms are interactions of the parameters. Storm events where snowmelt caused the runoff volume to exceed the precipitation amount were not included when developing the predictive equation or when using it.

Using the equations developed (Table 2), the Q_p for the study period was calculated using the observed P, I and M. The Q_p and the observed runoff (Q_o) are listed in Table 3. A comparison of Q_p with Q_o shows that WS 110 (summer rotational grazing only) did not have a marked change in hydrology, observed flow being only 1.2 times greater than predicted. WS 106 (winter rotational grazing on autumn regrowth and feeding field stored hay) had an

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TABLE 2. COEFFICIENTS OF THE RUNOFF PREDICTION EQUATION* FOR WS 106, 110 and 129 WITH THE RESPECTIVE COEFFICIENT OF DETERMINATION (R^2)

Watershed	x	a	b	c	d	e	f	g	R^2	Years in meadow	Number of events
WS 106	-0.0959	0	-0.180	0	0.00098	0.00632	0.00147	0	0.796	13	281
WS 110	2.663	-0.355	0	-0.0453	0.00438	0	0.00525	0.0019	0.782	12	452
WS 129	1.06	-0.143	0	-0.0168	0.00143	0.00351	0.00206	0	0.702	23	733

*$Q_p = x + aP + bI + aM + dPP + ePI + fPM + gMI$

TABLE 3. PREDICTED AND OBSERVED RUNOFF VOLUMES (Q) FOR WS 106, 110 and 129

Season (Period)*	Predicted Q (mm)	Observed Q (mm)	No. of events
WS 106			
1977 growing	14.6	6.3	13
1977-78 dormant	15.5	13.9	21
(1977-78 water-year)	(30.1)	(20.2)	(34)
1978 growing	16.1	10.5	29
1978-79 dormant	22.5	63.1	20
(1978-79 water-year)	(38.6)	(73.6)	(49)
1979 growing	14.9	53.8	16
Total for study period	83.6	147.6	
WS 110			
1977 growing	30.6	14.8	14
1977-78 dormant	14.9	28.3	12
(1977-78 water-year)	(45.6)	(43.0)	(26)
1978 growing	36.0	20.9	17
1978-79 dormant	24.4	24.4	12
(1978-79 water-year)	(60.4)	(45.2)	(29)
1979 growing	48.8	96.0	11
Total for study period	157.7	184.4	
WS 129			
1977 growing	33.0	57.0	38
1977-78 dormant	7.2	79.1	30
(1977-78 water-year)	(40.2)	(136.1)	(68)
1978 growing	33.8	99.3	40
1978-79 dormant	8.5	49.4	27
(1978-79 water-year)	(42.2)	(148.7)	(67)
1979 growing	37.7	114.4	19
Total for study period	120.2	399.2	

*Growing season is May-Oct. Dormant is Nov-Apr. Water-year is May-Apr.

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observed flow 1.8 times that predicted. WS 129 (summer rotational grazing and winter feeding with hay) had an observed flow three times larger than predicted. It was during the dormant season that the marked increase in flow occurred on WS 129 and to a lesser degree on WS 106. Therefore, winter pasturing of livestock has a marked effect on increasing the runoff.

It is noted that the ratio of Q_o to Q_p for WS 106 and 110 in the GS 1979 was much larger than the preceding two GS. This was probably due to much more precipitation than usual from August to October (Figure 6). There is the possibility that the pasturing regime was also changing in the long term the hydrology on WS 106 and 110 during the growing season.

Runoff Curve Numbers

Calculating direct storm runoff volume by using runoff curve numbers is a common practice (USDA,1972) of the United States Department of Agriculture (USDA) Soil Conservation Service (SCS). The algebraic and hydrologic relations between storm rainfall, soil-site storage, storm runoff and curve number are as follows:

$$Q = \begin{cases} \dfrac{(P-0.2S)^2}{P + 0.8S} & , P \geq 0.2S \\ 0 & , P < 0.2S \end{cases} \qquad (1)$$

$$CN = \frac{1000}{10 + S} \qquad (2)$$

where: P = storm rainfall; Q = direct runoff; S = a watershed storage (soil moisture) parameter and CN = a dimensionless expression of S called "curve number".

The CN may vary from 0 where $Q = 0$ to 100 where $Q = P$. The equations as developed are in inches, thus the following analysis used inches in evaluating the study watersheds for the effect of pasturing on CN.

Cooley and Lane (1980) developed optimized curve numbers (OCNs) by using observed runoff volumes and computed runoff volumes from equation (1). With both rainfall and runoff data available, the S (or CN) was optimized. By minimizing the objective function SS, the optimal CN is found.

$$SS = \sum_{i=1}^{n} (Q_i - \hat{Q}_i)^2$$

where Q_i is observed runoff volume and $\hat{Q}_i$ is computed runoff volume and n is the number of storm events in the data set. If the coefficient of determination, r^2, is near zero, the use of equation (1) is not reliable. Values of r^2 near one would indicate that the OCN estimate is reliable.

Using the data from WS 106, WS 110 and WS 129 and the procedures of Cooley and Lane (1980) OCNs were developed for these watersheds to indicate

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hydrologic changes due to pasturing. OCNs from the previous years when the watersheds were in meadow and during the present study were developed (Table 4). The NLIN routine in the SAS computer package (Barr et al., 1976) was used to evaluate the OCNs.

The changes in OCNs due to the effects of the three livestock pasturing regimes are listed in the right column of Table 4. The OCNs developed for the meadow years showed better correlation during the growing season than during the dormant season. This difference is not unexpected as the CN development is better suited to the summer, convection storm than the winter, cyclonic storm. It is noted that the meadow year OCNs are similar on WS 106 and WS 129. WS 110 had larger OCNs during the meadow years, indicating that WS 110 normally had a larger runoff volume in relation to the amount of precipitation.

The changes in the OCNs from the meadow years to the study period were small for WS 110, +1 for DS and -3 for GS. The OCNs for the GS on WS 106 and WS 129 increased by 5 and 17, respectively. The OCNs for the DS on WS 106 and WS 129 increased by 16 and 27, respectively.

Therefore, based on the OCNs comparison, the summer rotational pasturing in WS 110 and the meadow in WS 106 did not affect the storm runoff volume. However, when winter feeding on WS 129 and winter pasturing/feeding on WS 106 was instituted, the hydrology changed with increased storm runoff occurring as indicated by larger OCNs. Even the hydrology on WS 129 during the summer changed with increased runoff, though not as much as in the winter.

Pasturing Effects on Hydrology

Both the linear regression equations and the OCNs method concluded that pasturing changed the hydrology of fields when changed from meadow to pasturing. Where good pasture management practices, e.g. fertilization, rotational grazing and no winter feeding were followed, the runoff volume was not affected as compared to previous meadow. Winter feeding did change the hydrology by increasing the volume of runoff. Rotational winter pasturing on fall regrowth and feeding field stored hay did not increase the runoff as much as when cattle were fed on one pasture the whole winter with hay brought from other areas. Wintering also affected the watershed with increased runoff during the growing season.

NUTRIENT CHEMISTRY

Stamper (1980) reviewed literature concerned with nutrient losses from agricultural watersheds. Table 5 lists values of runoff nutrient concentrations and annual nutrient flux for different land uses. The soluble nutrient yields from pasture/rangelands and forested watersheds are comparable. The soluble nutrient yields from row crops are from two to ten times larger than those from pastures/rangelands. There are several reasons that account for the range of values found in Table 1. The reasons are: physical differences in the monitored watersheds, differences in cover and differences in

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TABLE 4. SUMMARY OF THE OPTIMIZED CURVE NUMBERS (OCNs) FOR WATERSHEDS 106, 110 AND 129 FOR PRIOR MEADOW YEARS AND FOR STUDY PERIOD

	OCNs	r^2	n	ΔOCN*
WS 106				
Meadow (10 years)				
DS	63	0.67	108	
GS	63	0.95	62	
Study period (3 years)				
DS	79	0.17	47	+16
GS	68	0.51	72	+ 5
WS 110				
Meadow (12 years)				
DS	78	0.70	52	
GS	72	0.81	47	
Study period (3 years)				
DS	79	0.28	36	+ 1
GS	69	0.36	47	- 3
WS 129				
Meadow (23 years)				
DS	59	0.30	51	
GS	66	0.78	96	
Study period				
DS	86	0.42	66	+27
GS	83	0.75	111	+17

[*] Change in OCNs from meadow years to OCNs for pasturing in present study.

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monitoring. Therefore, for purposes of comparison, individual values of the parameters are less important than their relationship.

The nutrient chemistry in the present study will be considered under factors affecting nutrient concentration and flux, sediment nutrients and soluble nutrients and variables affecting nutrient and sediment transport.

TABLE 5. RANGES OF NUTRIENT CONCENTRATIONS AND NUTRIENT FLUX FOR VARIOUS LAND USES*

Land Use	Sol N	Sol P	Sol K	Sed N	SedP	Sed K
	mg/l(Kg/ha)					
Row Crops	1.5-37	0.23-0.95	--	1200-1300	--	--
Traditional cultivation	(0.37-4.0)	(0.19-0.66)	(0.58-4-56)	(0.09-147.0)	(33.2)	(0-7.6)
Pastures and	0.64-2.22	0.022-0.068	--	--	90	--
Rangeland	(0.25-12.1)	(0.074-1.27)	(1.74-10.2)	(1.21-3.7)	(0.07)	(--)
Forested	0.79	0.015	0.7-2.23	--	--	--
Watersheds	(2.45-3.9)	(0.048)	(6.91)	(1.0)	(--)	(--)

*Adapted from Stamper, 1980.

Nutrient Concentration and Flux

All rainfall and runoff events during the study period were monitored. The runoff events were studied in two groups: (1) all runoff events and (2) selected events which provided five or more discrete (periodic) samples. The characteristics of the selected events are tabulated in Appendix C. There were 27 runoff events in this group for WS 106, 21 events for WS 110 and 48 events for WS 129.

Initially, the rainfall hyetograph, the runoff hydrograph and the soluble nutrients concentration graphs were plotted on a Versatex Plotter for the selected runoff events. All three plots, the hyetograph, the hydrograph and the nutrient plots, had storm time as a common abscissa with the same scale (127 mm = one hour). The large scale was beneficial in comparing storms, but for the long duration storms the plots became difficult to work with. Because of the variation in storm intensity and length, visual comparison of the plots was not useful. As a result, it was decided to use data in a numerical form that could be evaluated using the computer and statistical programs.

One observation involving the graphs was that the nutrient concentration within a particular runoff event seemed relatively constant through the runoff event regardless of the shape of the hyetograph or the hydrograph. On the other hand, there was a great deal of variation in nutrient concentrations between the runoff events. Therefore, plots were made with normalized

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cumulative runoff volume and normalized nutrient flux. On these plots, the abscissa ranged from 0% to 100% with 100% representing the end of the runoff event as total runoff volume. Similarly, the ordinate value of nutrient flux was normalized ranging from 0% to 100%.

Composite nutrient flux scatter plots were made for each study watershed. Data were grouped for the water year (Nov-Oct), the dormant season (Nov-Apr) and the growing season (May-Oct). Figures 7-13 present the scatter plots for all three years on WS 129 for Tot N, Min N, Org N, P, K, COD and TOC. The remaining scatter plots for watersheds 106, 110 and 129 are given in Appendix D. Most of the points in these plots lie close to the 45° line connecting the origin and the (100%, 100%) point. This indicates that the nutrient concentration is generally constant throughout a runoff event.

It must be noted that this type of plot has a built-in bias since it is cumulative in nature. The plot for individual runoff events is constrained to go through the origin and the (100%, 100%) coordinate. Stamper, (1980) statistically evaluated these plotted points to determine if cumulative nutrient flux was correlated with cumulative runoff volumes. Stamper showed that when percent cumulative nutrient flux (dependent variable) is regressed against percent cumulative runoff volume, any number of higher order exponents were shown to be statistically significant at the 10% level. This phenomena was due to the bias noted above.

Another approach used by Stamper, (1980) was to develop confidence intervals (CI) on the nutrient flux data to evaluate whether the experimental data followed a linear delivery of nutrients with runoff water. For a particular percent runoff volume, e.g., 50%, the corresponding percent nutrient flux points for a group of data (e.g. all events in WS 129) could be used to establish a mean, variance and 90% and 95% confidence intervals. The CI were constructed at the selected percent cumulative runoff points (10%, 25%, 50%, 75% and 90%). As shown in Figures 14-16, a curve was drawn between the data points for each discrete sample in a runoff event. The corresponding percent cumulative flux points for 10%, 25% etc. of cumulative runoff volume were obtained. The CI for the nutrient flux variations were then calculated. Appendix E explains the procedure for calculating the confidence intervals.

The confidence intervals were evaluated for different data groupings: all events, separate dormant seasons, separate growing seasons, all dormant seasons in study, all growing seasons in study, small runoff events (<0.75 cm) and large runoff events (<0.75 cm). A summary of the CI analysis on the Tot N, Min N, Org N, P and K is in Appendix F. Table 6 gives the apparent trends in the nutrient flux delivery data. Early delivery (ED) means that the nutrient flux comes off the watershed ahead of the runoff volume. Matched delivery (MD) means that the nutrient flux corresponds directly to the runoff volume, i.e. 50% runoff volume has carried 50% of the nutrient flux. Late delivery (LD) indicates that the bulk of the nutrients comes off the watershed in the last half of the runoff volume.

In most of the data groupings in Appendix F, as summarized in Table 6, matched delivery was observed. The exceptions were mostly ED except for P where two exceptions were LD. However, as noted in Appendix F, the

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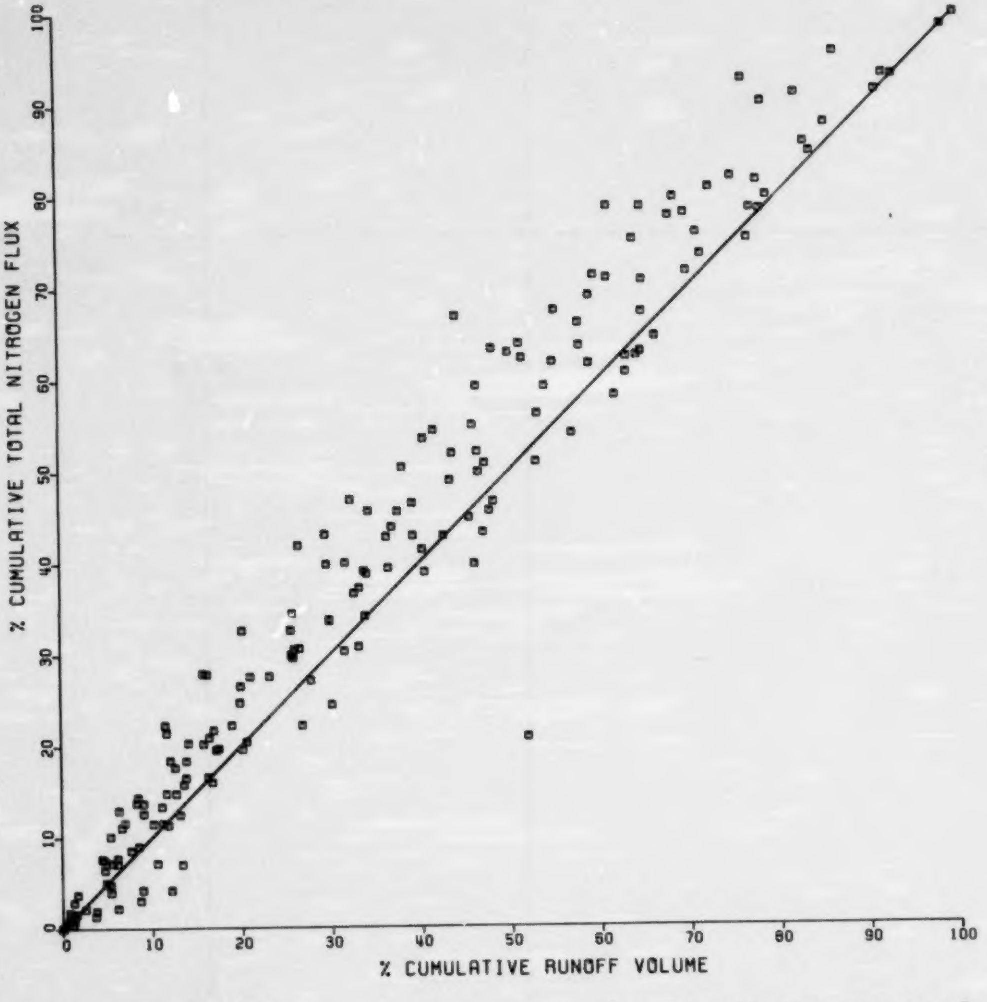

Figure 7. Total nitrogen flux scatter plot for all discrete samples in all selected runoff events from WS 129 during study period

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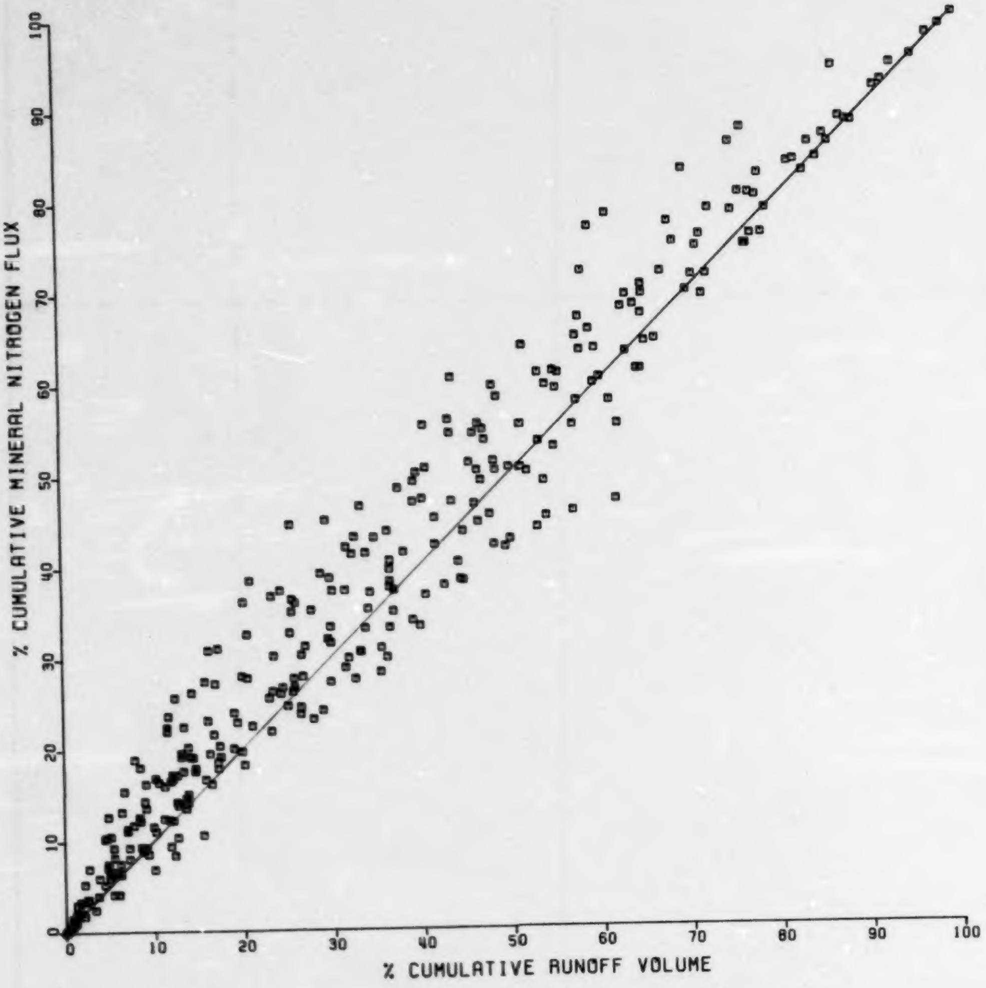

Figure 8. Mineral nitrogen flux scatter plot for all discrete samples in all selected runoff events from WS 129 during study period.

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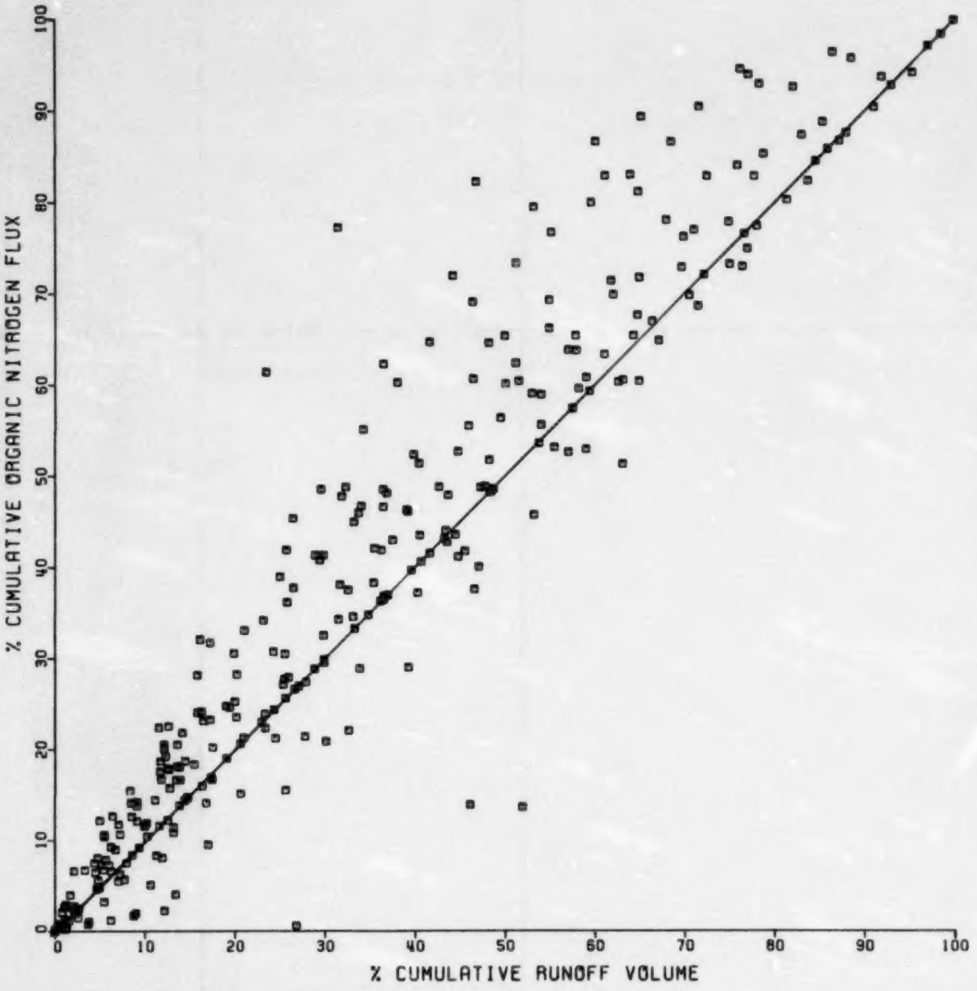

Figure 9. Organic nitrogen flux scatter plot for all discrete samples in all selected runoff events from WS 129 during study period.

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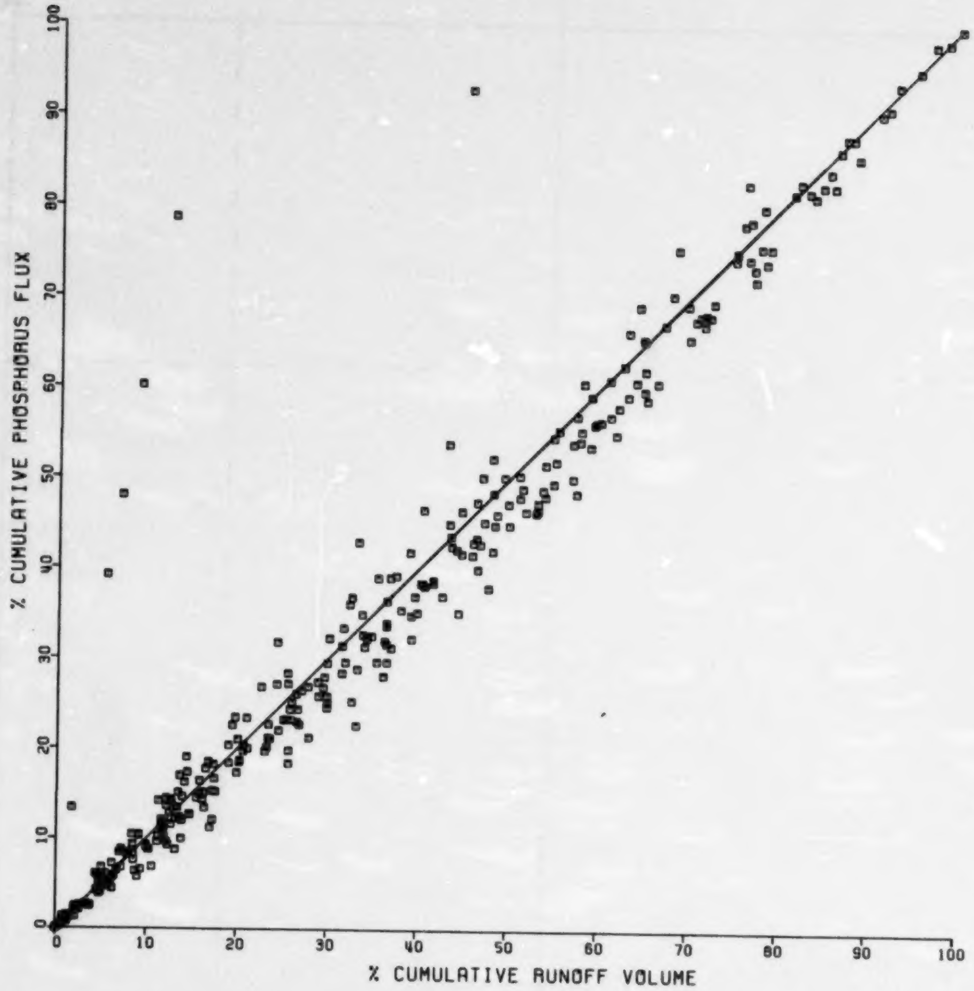

Figure 10. Phosphorus flux scatter plot for all discrete samples in all selected runoff events from WS 129 during study period.

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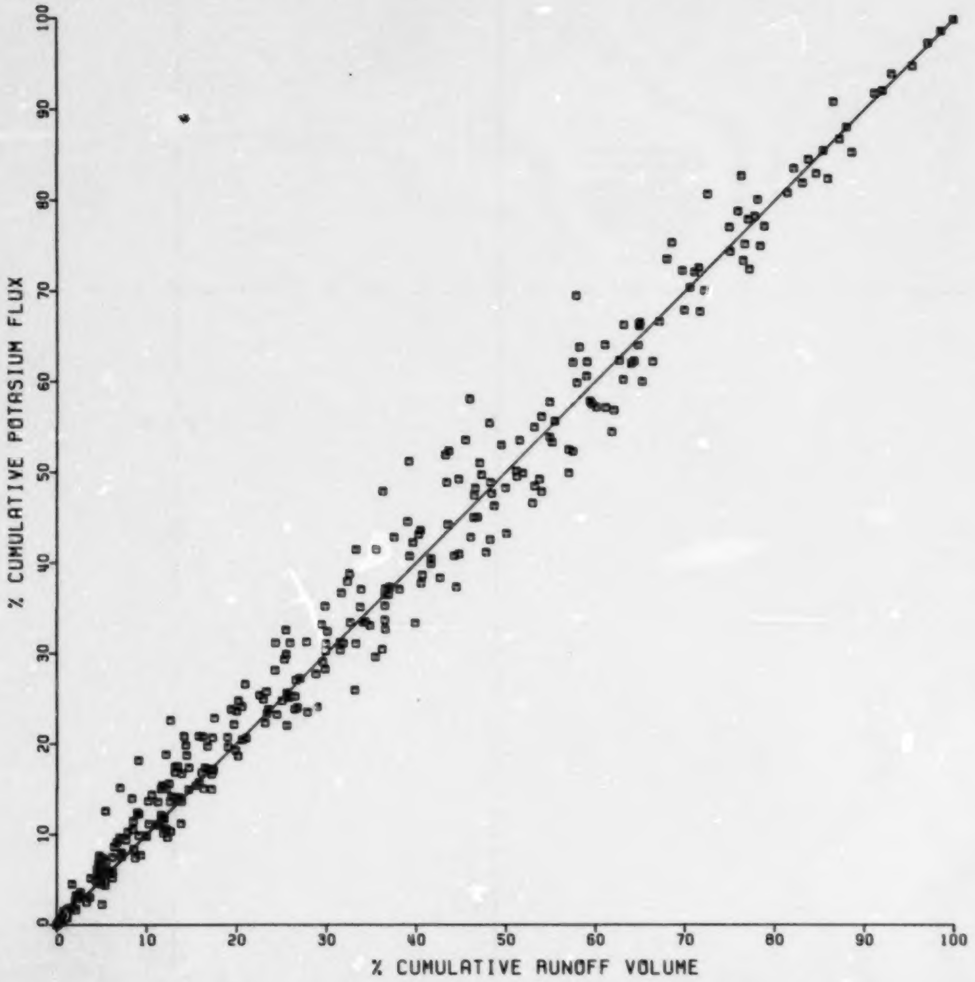

Figure 11. Potassium scatter plot for all discrete samples in all selected runoff events from WS 129 during study period.

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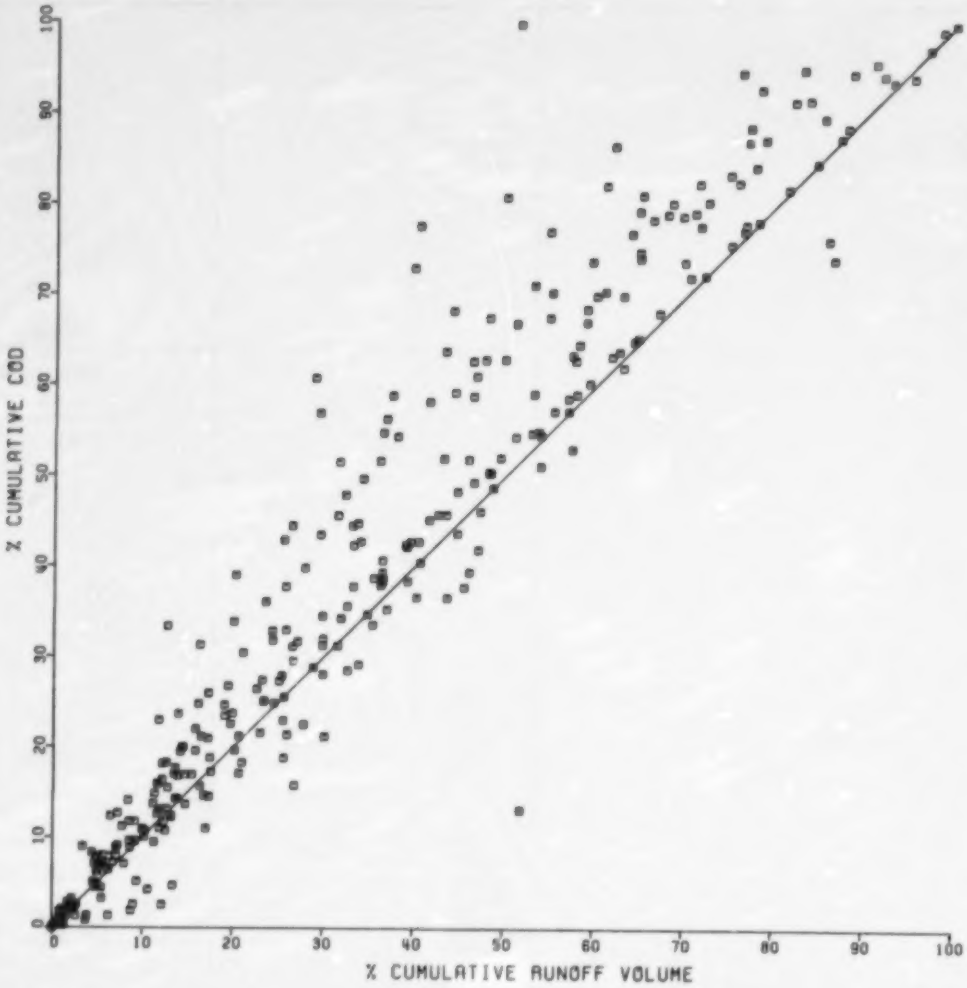

Figure 12. Chemical oxygen demand scatter plot for all discrete samples in all selected runoff events from VS 129 during study period.

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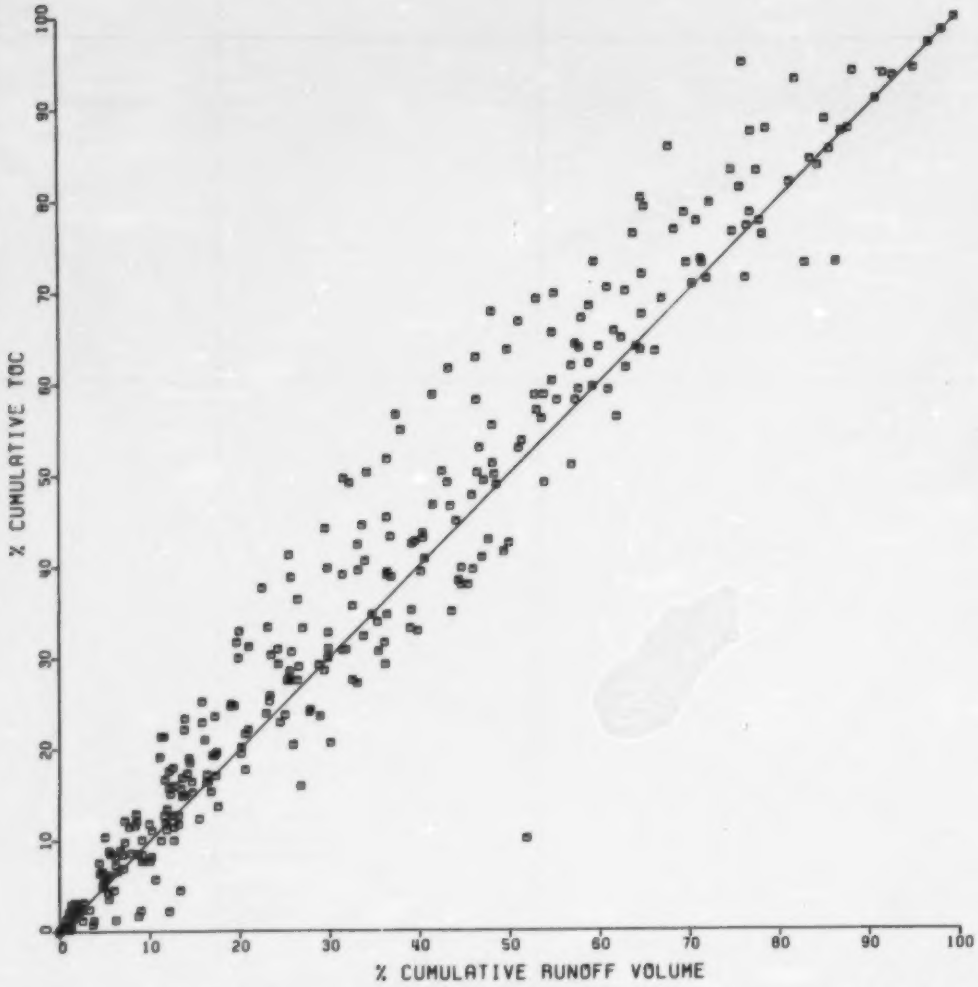

Figure 13. Total organic carbon scatter plot for all discrete samples in all selected runoff events from WS 129 during study period.

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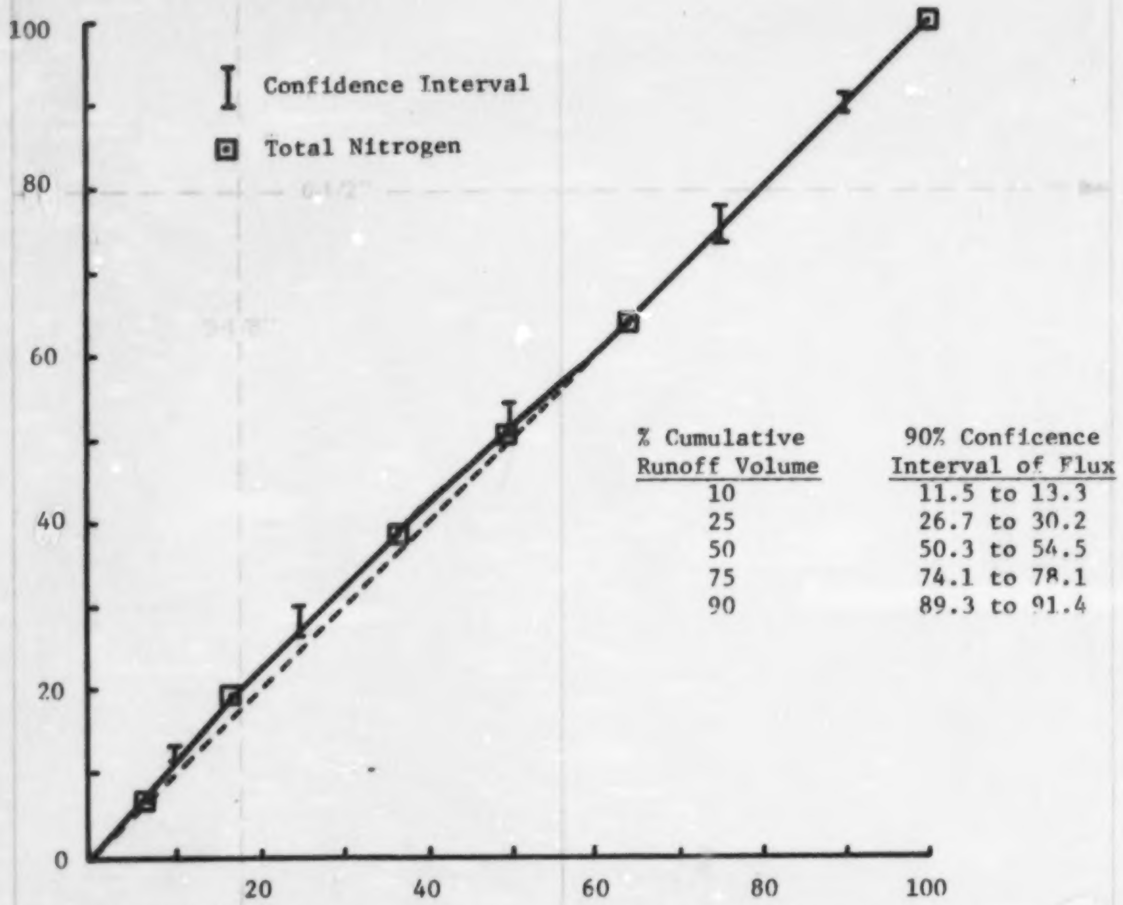

% Cumulative Runoff Volume	90% Conficence Interval of Flux
10	11.5 to 13.3
25	26.7 to 30.2
50	50.3 to 54.5
75	74.1 to 78.1
90	89.3 to 91.4

Figure 14. Typical percent cumulative nitrogen flux plot resulting from a runoff event on watershed 106 on September 14, 1979.

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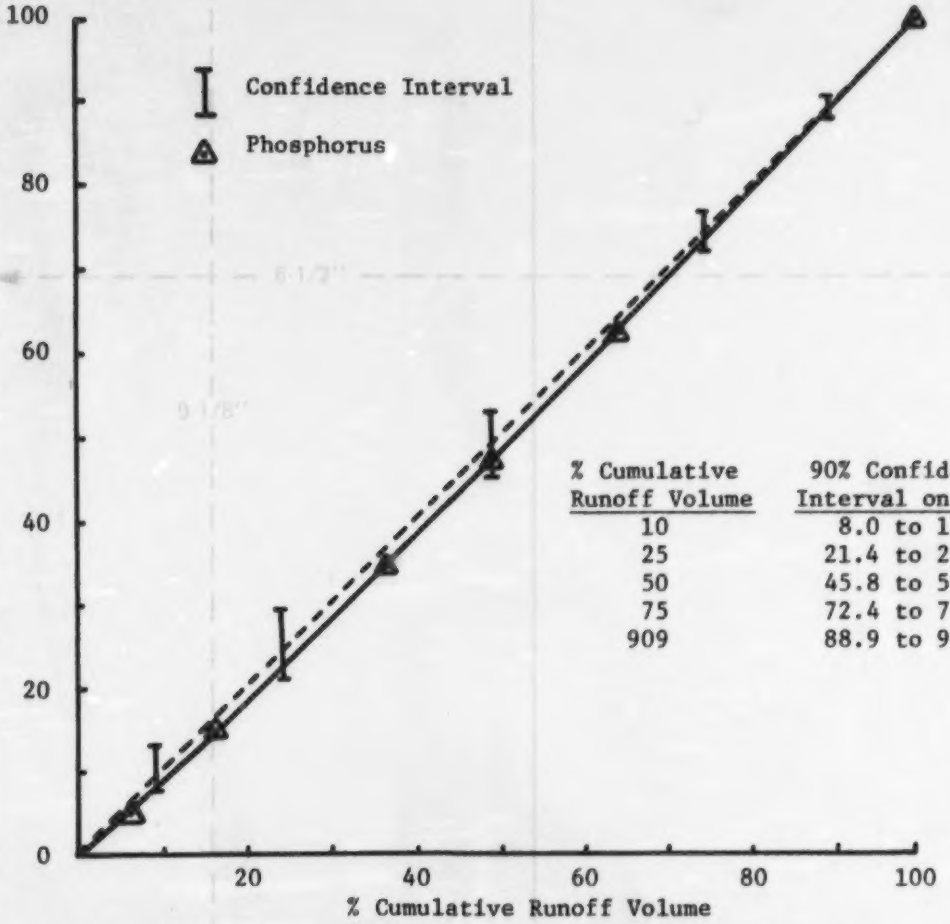

% Cumulative Runoff Volume	90% Confidence Interval on Flux
10	8.0 to 13.4
25	21.4 to 29.3
50	45.8 to 53.4
75	72.4 to 77.0
909	88.9 to 90.9

Figure 15, Typical percent cumulative phosphorus flux plot resulting from a runoff event on watershed 106 on September 14, 1979.

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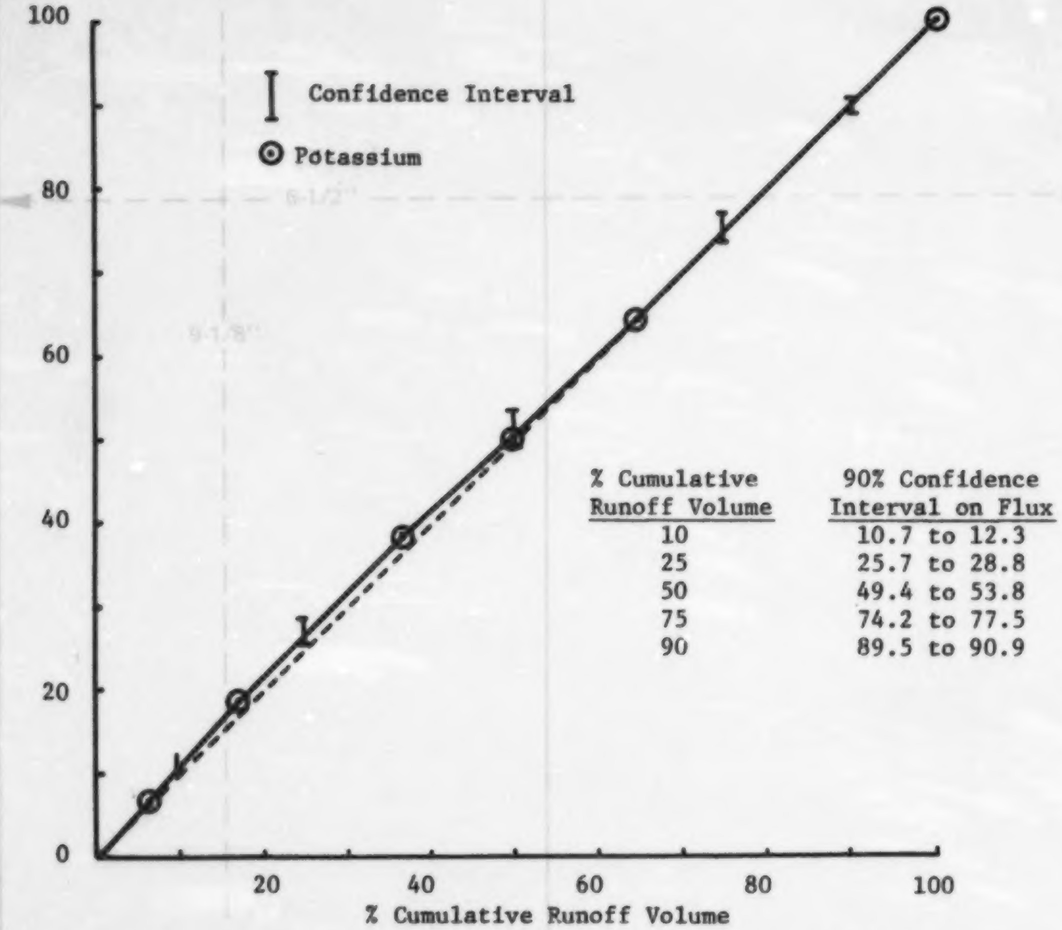

% Cumulative Runoff Volume	90% Confidence Interval on Flux
10	10.7 to 12.3
25	25.7 to 28.8
50	49.4 to 53.8
75	74.2 to 77.5
90	89.5 to 90.9

Figure 16. Typical percent cumulative potassium flux plot resulting from a runoff event on watershed 106 on September 14, 1979.

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confidence interval that excluded the MD points did so by only a small amount. The percents noted in the 90% CI are the range by which the observed nutrient flux fell outside the CI. Only those points which fell outside MD by 2 or 3% were not MD on the 95% confidence interval. Therefore, even where ED was indicated it did not differ greatly from MD and any error made by assuming matched delivery in all cases would be minimal.

TABLE 6. APPARENT TRENDS IN THE NUTRIENT FLUX DELIVERY DATA*

Nutrient	Watershed	Delivery#	Comments
Tot N	All	ED	--
	106	Mostly MD	2 of 11 groups - ED
	110	Mostly MD	3 of 10 groups - ED
	129	Mostly ED	4 of 10 groups - MD
Min N	All	ED	--
	106	Mostly MD	4 of 11 groups - ED
	110	Mostly MD	1 of 10 groups - ED
	129	Mostly ED	4 of 11 groups - MD
Org N	All	ED	--
	106	MD	--
	110	Mostly MD	3 of 10 groups - ED
	129	Mostly MD	4 of 11 groups - ED
P	All	MD	--
	106	MD	1 of 11 groups - LD
	110	MD	--
	129	MD	1 of 11 groups - LD
K	All	ED	--
	106	MD	--
	110	Mostly ED	2 of 10 groups - MD
	129	Mostly MD	2 of 11 groups - ED

*Based on the data in Appendix F for the 90% CI which is narrower than the 95% CI.

#MD = match delivery of nutrients with runoff; ED = early delivery; LD = late delivery.

Sediment Analysis

In order to evaluate the contribution of the nutrients from the sediment transported in the runoff water, the soluble nutrient flux and the sediment nutrient flux were calculated (expressed in units of kg/ha). A summary of the nutrient fluxes for the selected runoff events is located in Appendix G. Stamper, (1980) analyzed the data in Tables G-1 to G-3 and reported that the mean of the Sed P to Sol P flux ratio was two to five times the N flux ratio mean. The Sed N to Sol N flux ratio mean was, in turn, an order of magnitude larger than the K flux ratio. This analysis indicated that P flux is associated with sediment transport more so than N flux, which in turn is more so than K flux. WS 129 had the highest flux ratios compared to WS 106 and 110 which implicate winter pasturing as a cause for more sediment transport.

The means of the soluble nutrient concentrations in Table G-4 exceed the literature values for the pastures/rangeland in Table 5. The nutrient concentration means for WS 129 were about twice those of WS 106, which in turn, were about twice as large as values for WS 110. This decreasing order of concentration means implicates winter pasturing (or feeding) as a contributer to nutrients in runoff.

Table 7 summarizes the nutrient flux for all runoff events in Table G-5. Tables G-1 - G-4 were for selected events that had five or more discrete samples which represented larger storm events. The data from Table G-5 are plotted in Figures 17-19 which give a visual summary of soluble and sediment nutrient flux. The following trends are evident from the data:

1. For each watershed, the sediment nutrient flux was largest for N and least for K.

2. WS 129 had the largest flux of each nutrient, soluble and sediment related, while WS 110 had the least.

3. WS 106 and 129 had more nutrient transport during the dormant season except for the very wet growing season in 1979.

These trends, again, implicate winter pasturing as a cause for increased nutrient transport.

Comparison of Study and Control Watersheds

A forested watershed (WS 172) was monitored to give base line data for comparison with the pasture watersheds. The total nutrient fluxes of N, P and K for each growing and dormant season are listed in Table 8. Monthly tabulations of runoff, mean nutrient concentration and nutrient flux are given in Table H-1. The total nutrient fluxes from WS 172 are plotted in Figure 20. Sediment was not separated from the sample.

The transport of N from the control watershed was of the same order of magnitude as WS 110 during growing and dormant seasons and as WS 106 during growing seasons. The N flux from WS 106 during the dormant season was about twice that of the control. The N flux from WS 129 was from four to eight times greater than from the control.

The P flux from the control watershed was very little, three to ten orders of magnitude less than the pasture watershed. This in part was due to very little sediment leaving the forested control watershed.

TABLE 7. SUMMARY OF TOTAL NUTRIENT FLUX FOR THREE STUDY WATERSHEDS

Time period*	Tot N Flux	Tot P Flux	Tot K Flux
Watershed 106		kg/ha	
GS 77	0.425	0.080	0.710
DS 77-78	4.196	0.476	7.796
GS 78	0.484	0.106	1.582
DS 78-79	7.101	0.918	14.297
GS 79	6.141	0.413	8.055
DS 79-80	10.493	0.932	16.974
Study period (3 years)	28.84	2.925	49.414
Watershed 110			
GS 77	1.418	0.303	1.509
DS 77-78	1.418	0.142	2.047
GS 78	1.435	0.327	3.550
DS 78-79	0.941	0.113	1.427
GS 79	14.230	0.773	14.446
DS 79-80	1.421	0.128	1.576
Study period (3 years)	20.863	1.786	16.022
Watershed 129			
GS 77	2.985	0.919	11.418
DS 77-78	15.871	2.557	32.790
GS 78	8.587	2.332	22.476
DS 78-79	16.528	3.118	24.651
GS 79	6.677	1.988	30.520
DS 79-80	22.154	2.931	21.412
Study period (3 years)	72.802	13.845	143.317

*GS = growing season (May-Oct) and DS = dormant season (Nov -Apr).

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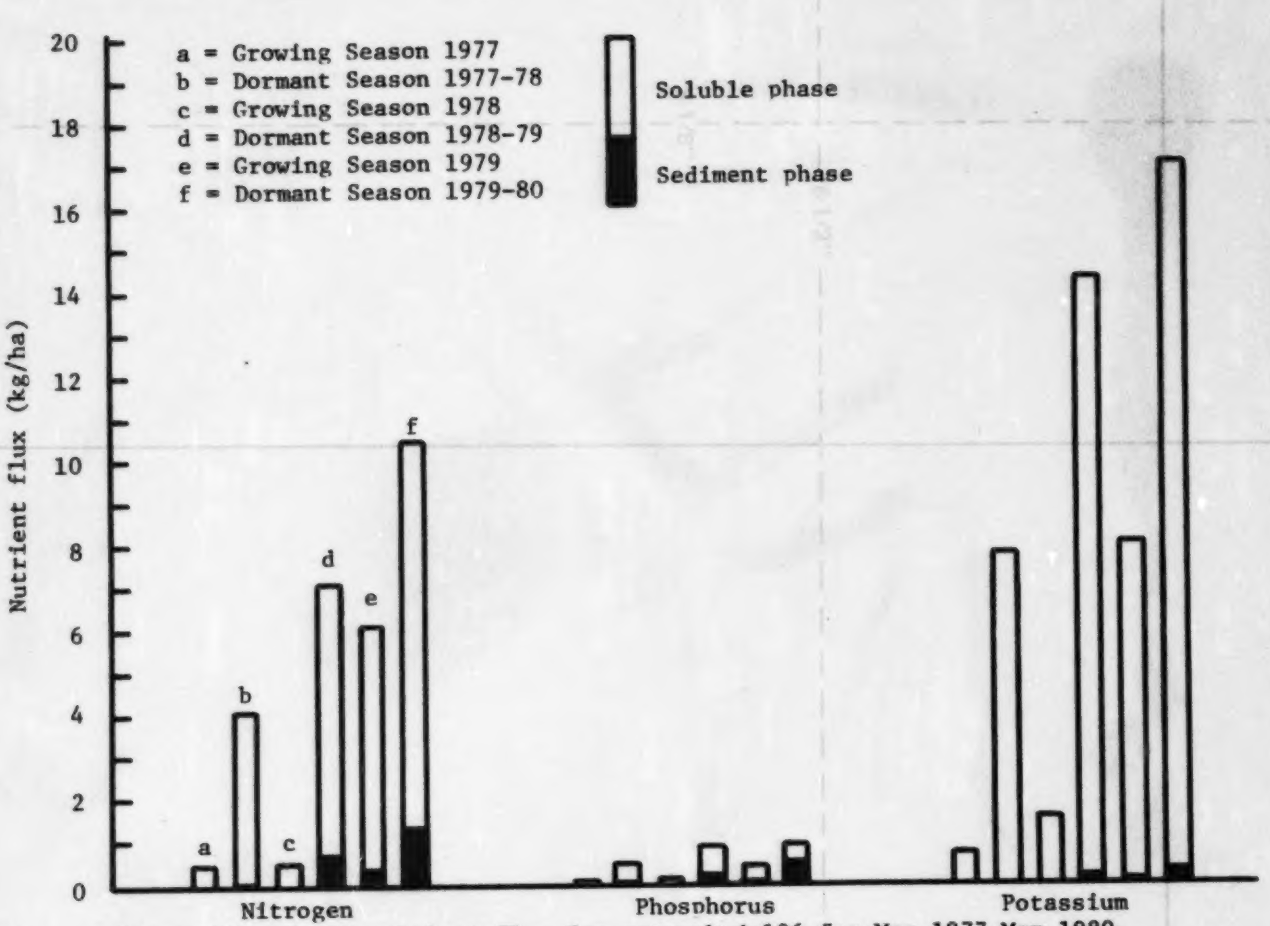

Figure 17. Total nutrient flux for watershed 106 for May 1977-Mar 1980.

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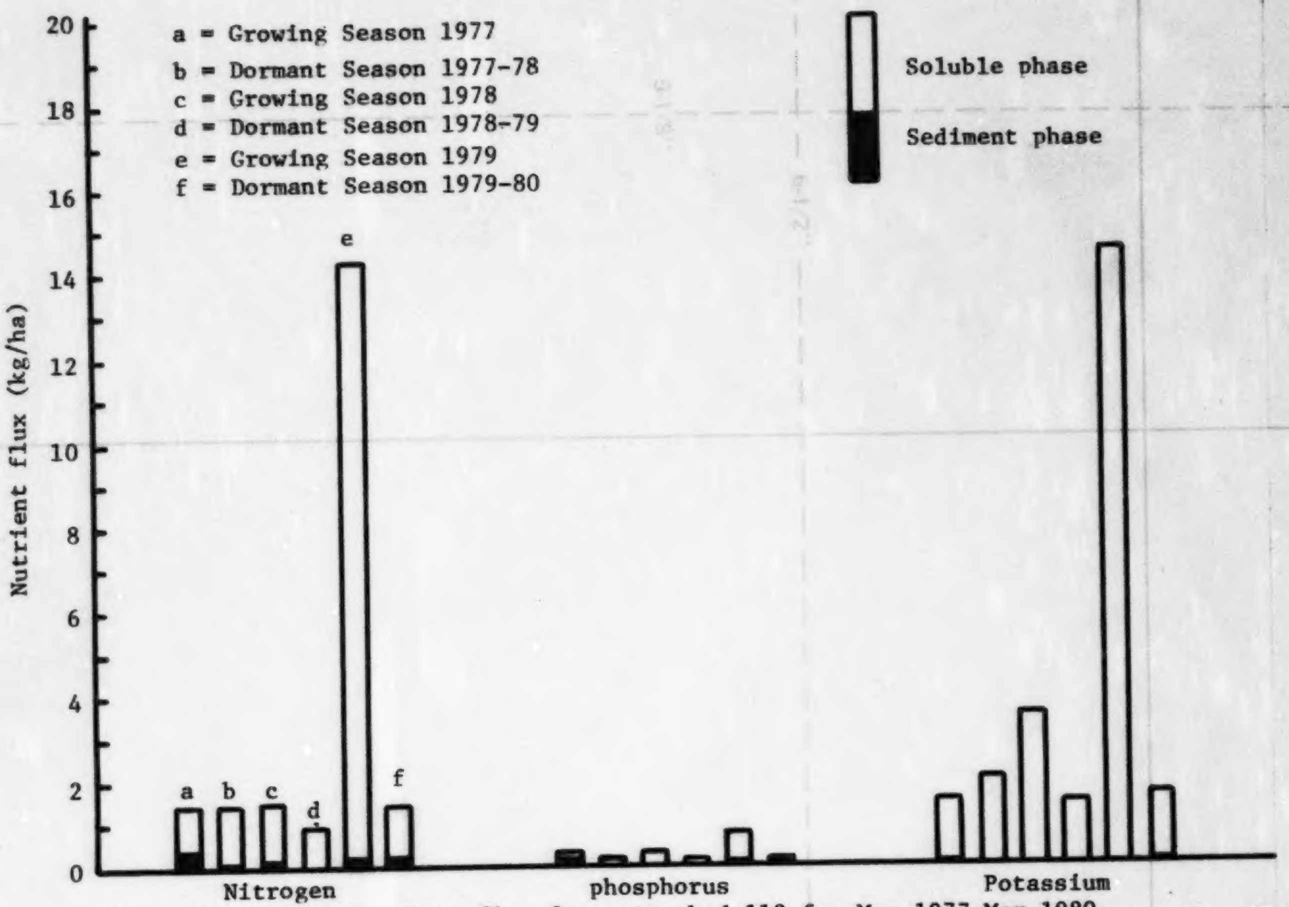

Figure 18. Total nutrient flux for watershed 110 for May 1977-Mar 1980.

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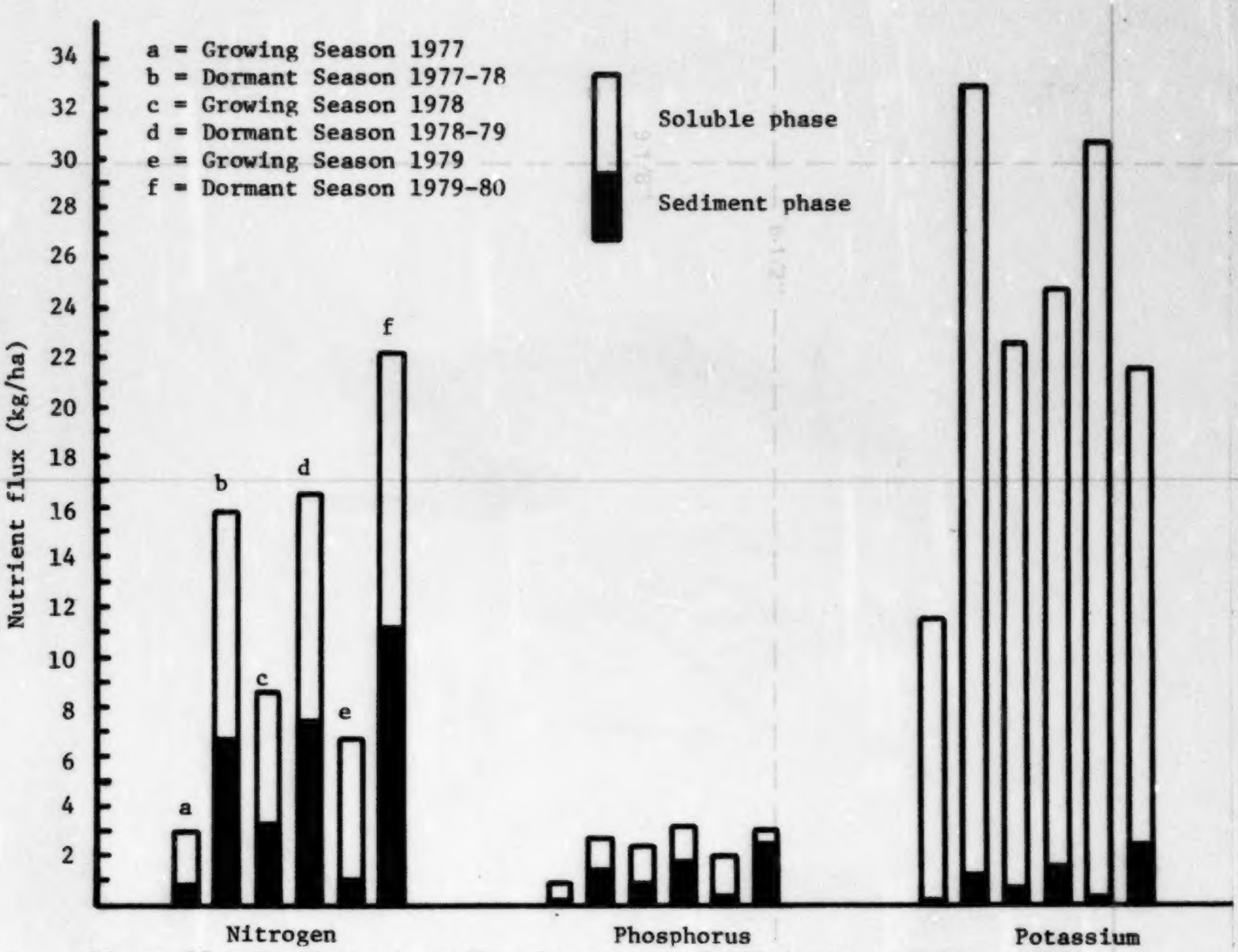

Figure 19. Total nutrient flux for watershed 129 for May 1977-Mar 1980.

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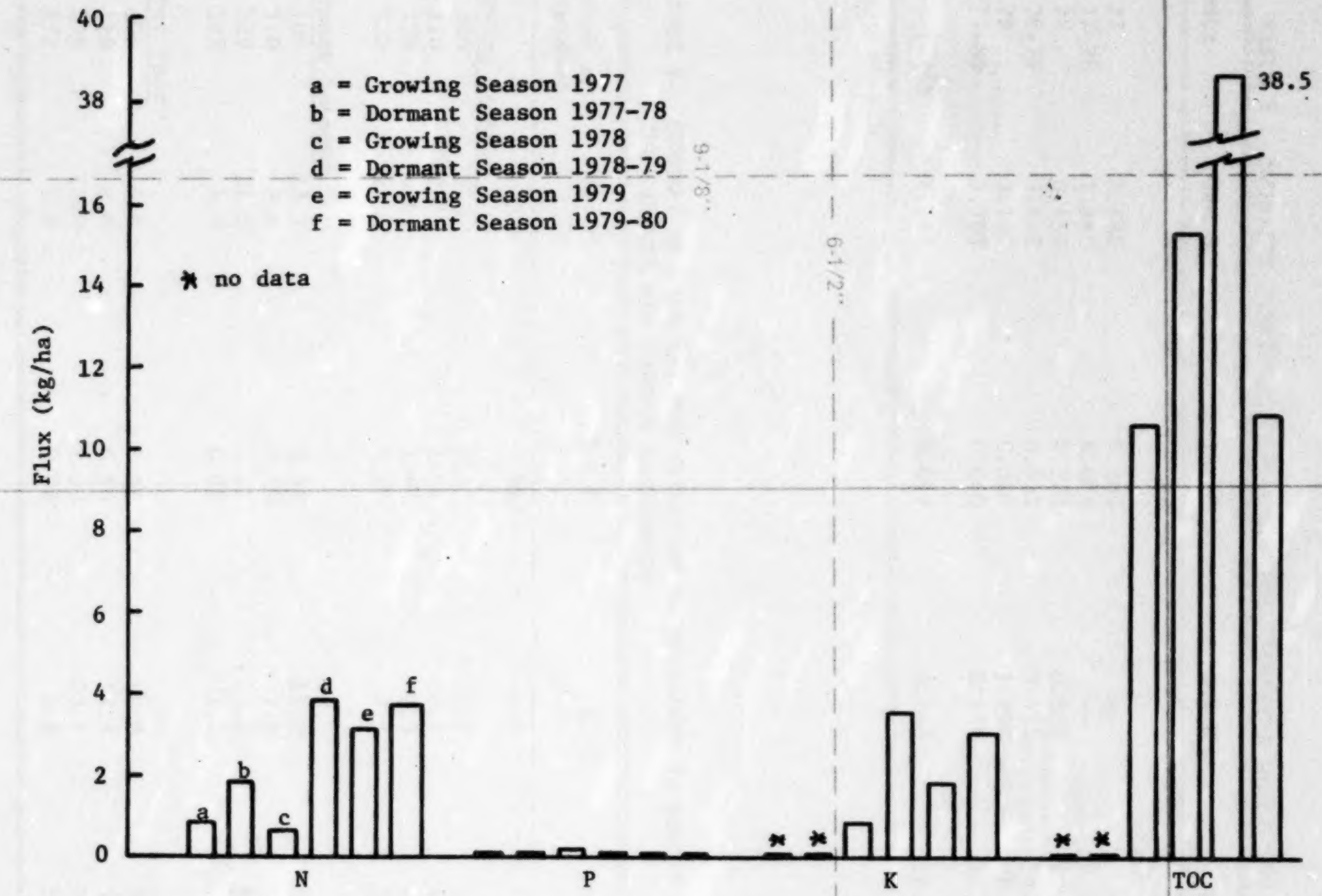

Figure 20. Total nutrient flux for control watershed (WS 172).

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TABLE 8 . NUTRIENT TRANSPORT FROM A CONTROL, FORESTED WATERSHED (WS 172)

Season	Tot N	Tot P	Sol K	TOC
	kg/ha			
GS 77	0.806	0.003	--	--
DS 77-78	1.860	0.023	--	--
GS 78	0.655	0.202	0.858	10.490
DS 78-79	3.846	0.035	3.455	15.171
GS 79	3.152	0.020	1.800	38.462
DS 79-80	3.705	0.060	2.959	11.778
Annual ($\bar{x}$)	2.337	0.057	2.268	18.975

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TABLE 9. SUMMARY OF MEAN ($\bar{x}$) CONCENTRATION OF NUTRIENTS IN RUNOFF FROM THE PASTURE AND CONTROL WATERSHEDS

Season & Watershed	Tot N	Tot P	K	TOC
	mg/ℓ			
Growing Seasons				
WS 106	6.3	1.13	20.7	34
WS 110	10.7	1.24	20.7	49
WS 129	6.4	1.87	9.9	55
WS 172	2.3	0.05	2.1	31
Dormant Seasons				
WS 106	13.2	0.69	15.2	38
WS 110	5.4	0.49	7.6	19
WS 129	21.5	2.02	45.2	85
WS 172	1.5	0.02	1.6	7
Water Year				
WS 106	9.8	0.91	17.9	36
WS 110	8.2	0.88	14.5	34
WS 129	12.9	1.93	25.1	70
WS 172	1.9	0.03	1.8	19

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The K flux from the control watershed was of the same order of magnitude as the K flux from WS 106 during the growing season and WS 110 during the dormant seasons when cattle were not on these pastures. The K flux from WS 106 during winter feeding and WS 110 during pasturing was about five times that from the control. The K flux from WS 129, summer grazing and winter feeding was about ten times that from the control.

The mean $(\bar{x})$ concentration of the nutrients in the runoff from the pasture and control watershed is given in Table 9. The nutrient concentration in the runoff from the pasture watershed is from four to 60 times larger than the control. A comparison of the runoff concentrations for the pastures during the growing season indicates that the high fertilization of WS 106 and 110 caused an increase in the N and K concentrations. During the dormant season pastures with livestock have a higher concentration of N, P and K in the runoff.

Organic Material in Runoff

A seasonal comparison of the average concentrations of TOC, COD and BOD for WS 106, WS 110 and WS 129 is given in Table 10. The data in Table 10 are a summary of data in Appendix I. The BOD concentrations of the runoff from the three pastures ranged from 15 to 18 mg/ℓ during the growing season. The BOD in the runoff from WS 110 during the dormant season was 9 mg/ℓ. The BOD in the dormant season from WS 106 and WS 129 was two and four times respectively, that of WS 110. No BOD or COD values were obtained for the runoff from the control watershed.

The COD concentration was about twice the TOC value and varied between the pastures in a similar manner to the BOD. The TOC in the control watershed runoff is given in Table 9. During the growing season the control and WS 106 (no summer grazing) were the same. The TOC in runoff from WS 110 and WS 129 were 55% and 75% respectively, greater than from the control. However, during the dormant season the TOC in the control runoff was from three to five to 11 times less than WS 110, WS 106 and WS 129, respectively. A comparison of the TOC flux from the pastures (Table 8) and the control watershed (Table 10) shows a similar relationship. The higher TOC concentration and flux are associated with cattle occupancy and time of occupancy.

Variables Affecting Nutrient Transport

Regression analyses were used to identify statistically significant hydrologic, agronomic and livestock management variables that would explain the variations in the nutrient concentrations in the runoff from the study pastures (Stamper, 1980).

Single factor regressions were used to establish whether independent variables were correlated with the dependent variable (nutrient concentration means). This analysis was conducted for both the soluble N, P and K and the sediment N, P and K. Independent variables regressed against the nutrient concentration means were: runoff volume, amount of precipitation, precipitation intensity factor, soil moisture, sediment flux, time after

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fertilizer application, percent vegetative cover, cattle on or off the pasture and a time factor (from the date of cattle on or off pasture).

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TABLE 10. SEASONAL COMPARISON OF MEAN ($\bar{x}$) CONCENTRATION AND MEAN ($\bar{x}$) FLUX FOR TOC, COD AND BOD

Watershed and season	Runoff*	Mean ($\bar{x}$) concentration#			Mean ($\bar{x}$) seasonal flux*	
		TOC	COD	BOD	TOC	COD
	-mm-	- - -	mg/ℓ	- - -	- - - kg/ha	- - -
WS 106						
Growing Seasons	24.2	34	66	18	3.5	8.2
Dormant Seasons	59.1	38	87	20	21.0	61.0
WS 110						
Growing Seasons	43.9	49	98	15	11.7	24.9
Dormant Seasons	37.7	19	50	9	5.4	10.3
WS 129						
Growing Seasons	90.3	55	115	17	34.0	89
Dormant Seasons	78.8	85	294	38	82.4	234

*Average of complete (6 month) seasons. See Appendix I.

#Average of all events in respective season during study period.

Runoff volume and time after fertilizer application were not found to be significant independent variables in explaining the variation in nutrient mean concentrations. The remaining variables varied in their correlation with the nutrient concentration means. Table 11 is a listing of significant independent variables as identified by single factor regression procedures. There were few easily identifiable patterns indicating that a particular variable was or was not correlated with a dependable variable.

A second procedure used by Stamper, (1980) to identify significant independent variables was stepwise regression. A summary of this stepwise regression procedure is listed in Table 12. The "best" set of independent variables for each nutrient and watershed combination is given along with its corresponding r^2 value. Variations between independent variables were such that no single "best" set could be identified to hold in all cases.

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TABLE 11. SIGNIFICANT INDEPENDENT VARIABLES AS IDENTIFIED BY SINGLE FACTOR REGRESSION ANALYSIS

Watershed	Dependent variables (nutrient concentrations)					
	Sol N	Sol P	Sol K	Sed N	Sed P	Sed K
WS 106	-- *	--	ON/OFF	ON/OFF #	ON/OFF #	ON/OFF #
	--	PRECIP	--	--	--	--
	RAINT	RAINT^2	--	--	--	--
	--	SOILM	--	--	--	--
	--	--	--	--	--	--
	TIME/0 #	--	TIME/0	TIME/0	TIME/0	TIME/0
	--	--	WHSED	#	#	#
WS 110	--	ON/OFF	ON/OFF	--	--	--
	--	--	--	--	--	--
	RAINT	--	RAINT	--	--	--
	--	SOILM	SOILM	--	--	--
	--	--	--	--	--	--
	TIME/0	TIME/0	--	TIME/0	TIME/0	TIME/0
	--	--	--	**	**	**
WS 129	--	--	--	ON/OFF	ON/OFF	ON/OFF
	PRECIP	--	PRECIP	PRECIP^2	PRECIP	PRECIP
	RAINT #	--	RAINT #	RAINT	RAINT	RAINT
	--	SOILM	--	SOILM	SOILM	SOILM
	COVER	--	--	COVER	COVER	COVER
	--	--	TIME/0	TIME/0	TIME/0	TIME/0
	--	--	--	**	**	**

*Missing values indicate that the correlation was not significant at the 10% level. The order of the independent variables is: ON/OFF (cattle on or off the pasture), PRECIP, RAINT (precipitation intensity factor), SOILM (antecedent soil moisture), COVER (percent cover), TIME/0 (time factor from when cattle went on or came off pasture) and WHSED (the sediment flux).

#These variables were marginally significant between the 10 and 12% level.

**Variable is not independent.

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TABLE 12. SUMMARY OF SIGNIFICANT INDEPENDENT VARIABLES AS IDENTIFIED BY STEPWISE REGRESSION

Watershed	Dependent Variables (nutrient concentrations)					
	Sol N	Sol P	Sol K	Sed N	Sed P	Sed K
WS 106	--[*]	--	--	--	--	--
	--	--	--	--	ON/OFF	ON/OFF
	--	PRECIP	PRECIP	PRECIP	--	--
	RAINT	--	--	--	--	--
	--	--	--	--	--	--
	--	TIME/O	TIME/O	TIME/O	TIME/O	TIME/O
	--	--	WHSED	#	#	#
	n=11	n=11	n=11	n=8	n=8	n=8
	r^2=0.29	r^2=0.82	r^2=0.93	r^2=0.84	r^2=0.85	r^2=0.87
WS 110	--	ON/OFF	--	--	--	--
	PRECIP	--	--	--	--	--
	RAINT	--	RAINT	--	--	--
	--	--	--	--	--	--
	--	--	--	--	--	--
	--	--	--	TIME/O	TIME/O	TIME/O
	--	--	--	#	#	#
	n=9	n=9	n=9	n=7	n=7	n=7
	r^2=0.96	r^2=0.68	r^2=0.68	r^2=0.88	r^2=0.90	r^2=0.94
WS 129	ON/OFF	--	--	ON/OFF	ON/OFF	ON/OFF
	--	--	PRECIP	--	--	--
	--	--	--	--	--	--
	--	SOILM	SOILM	--	--	--
	COVER	--	--	--	COVER	--
	--	--	--	--	--	--
	--	--	--	#	#	#
	n=23	n=23	n=23	n=14	n=14	n=14
	r^2=0.47	r^2=0.32	r^2=0.32	r^2=0.85	r^2=0.93	r^2=0.87

[*] The order of the independent variable is the same as in Table 11.

[#] Not included because variable is not independent.

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Generally, the soluble nutrient concentration means were a function of the hydrologic variables: precipitation (PRECIP), rainfall intensity (RAINT) and antecedent soil moisture (SOILM). The agronomic variable of vegetative cover (COVER) was identified in only one regression.

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The sediment nutrient means were a function of the livestock management variables, ON/OFF (cattle on or off the pastures) or TIME/0 (time factor from when cattle went on or came off pasture). WS 106 and WS 110 had only rotational grazing and the time factor from when the cattle went on and off was significant. WS 129 had cattle all winter as well as summer rotational grazing and the variable ON/OFF was significant.

MICROBIOLOGY

Runoff water samples were collected periodically from the watershed runoff plots during 1977-1979 and transported in an ice chest to the Soil Microbiology laboratory at The Ohio State University. All analysis for bacteriological quality were initiated within one hour after the samples arrived at the laboratory. When possible, water samples were collected at both the beginning and the end of the runoff events.

Each water sample was analyzed for numbers of total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS). Duplicate estimates were made for each of the indicator bacteria from each water sample.

Total coliforms were estimated using a tube MPN procedure in lauryl tryptose broth with 5 tubes per dilution (Presumptive Test). A confirmatory test was made of the presumed positive tubes in brilliant green lactose bile broth fermentation tubes. Both procedures are described in Standard Methods (APHA, 1975). Incubation temperatures were 35 ± 0.5°C.

Fecal coliforms were estimated using a Membrane Filter technique with M-FC medium as described in Standard Methods (APHA, 1975). The filters were incubated in a water bath at 44.5 ± 0.2°C for 24 hours.

Fecal streptococci were estimated by dilution plating on KF-Streptococcus agar with three replicate plates per dilution. The plates were incubated at 35 ± 0.5°C for 48 hours before counting (APHA, 1975). KF-Streptococcus agar rather than Pfizer's Selective Enterococcus agar (PSE) was used since Brodsky and Schiemann (1976) have shown a better recovery of streptococcal biotypes on KF agar. However, Doran and Linn (1979) considered PSE to be the best medium for studies of runoff from bovine pastures. Choice of medium is important in using the FC/FS ratio for identifying the source of fecal contamination.

The estimated numbers of TC, FC and FS in runoff waters from four watersheds with varying degrees of animal occupancy are shown in Figures 21 - 24. The period of occupancy over a two-year period is shown by the shaded areas on the top of each figure and varied from none on WS 172, to WS 129 which had the greatest occupancy. Watersheds 110 and 106 had limited occupancy.

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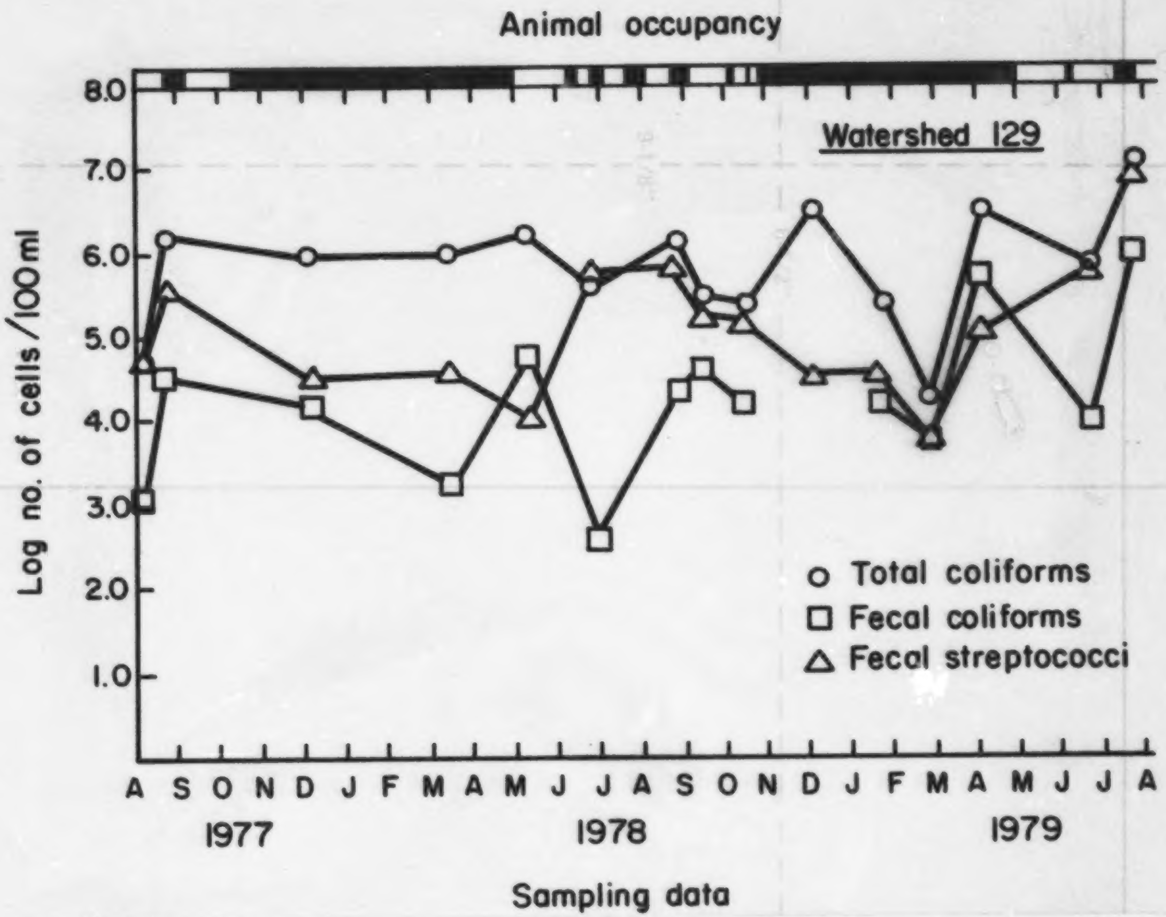

Figure 21. Numbers of TC, FC and FS in runoff water from WS 129 for the sampling dates indicated. Values are means of "beginning" runoff events and "end" runoff events.

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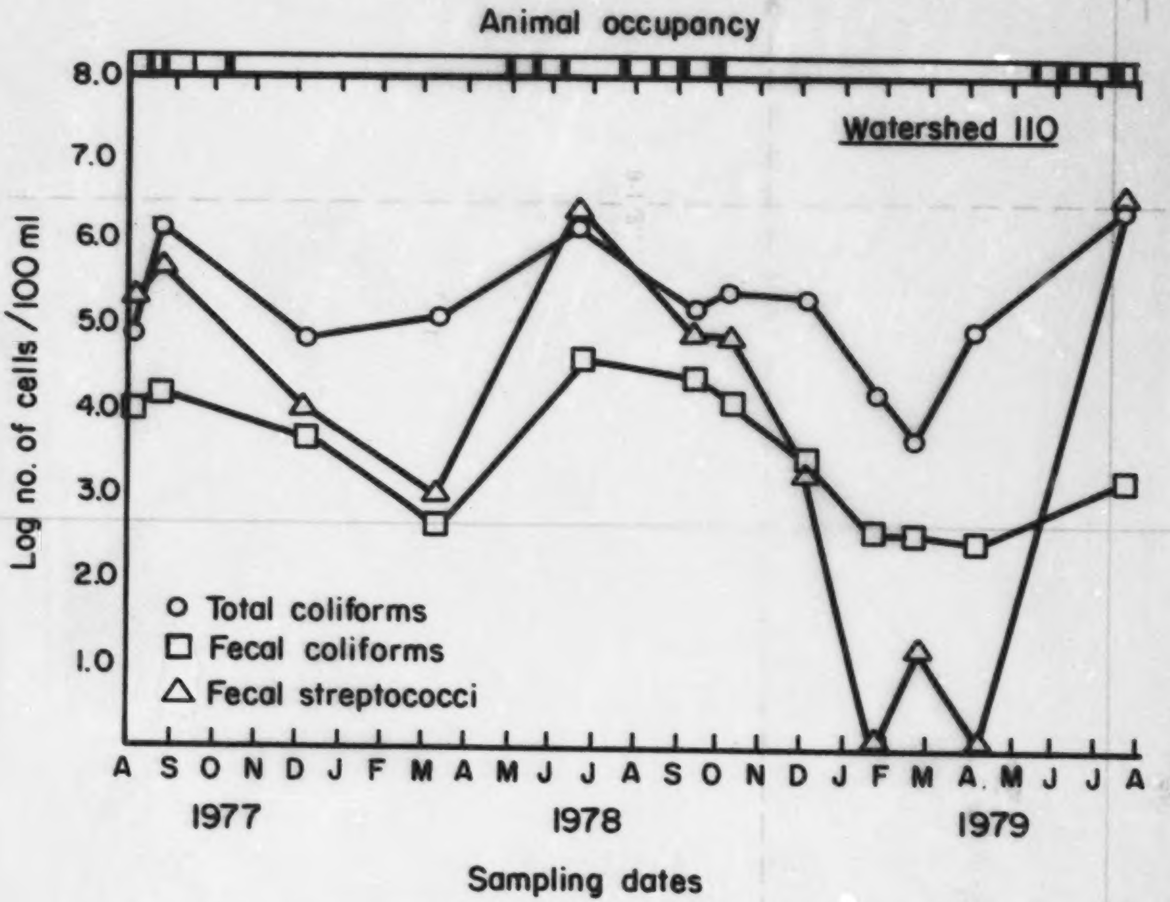

Figure 22. Numbers of TC, FC and FS in runoff water from WS 110 for the sampling dates indicated. Values are means of "beginning" runoff events and "end" runoff events.

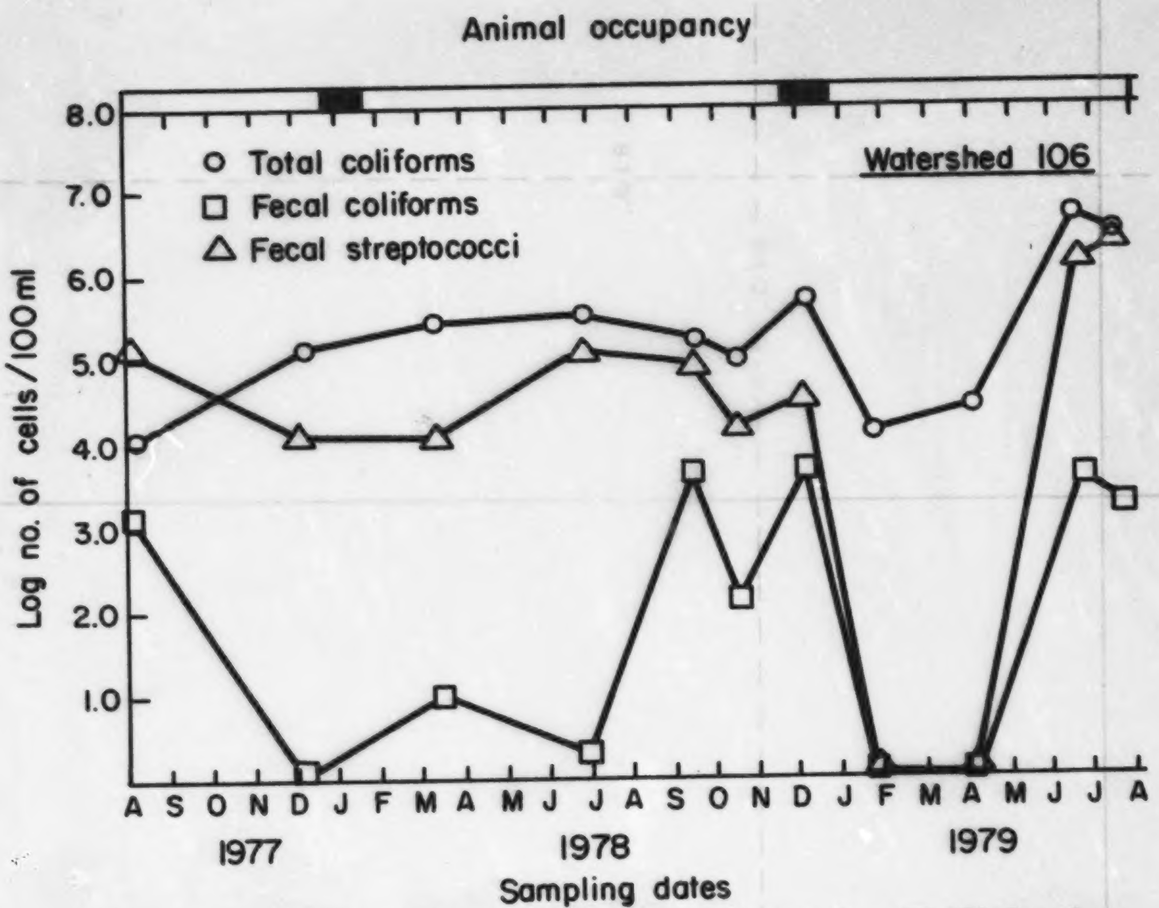

Figure 23. Numbers of TC, FC and FS in runoff water from WS 106 for the sampling dates indicated. Values are means of "beginning" runoff events and "end" runoff events.

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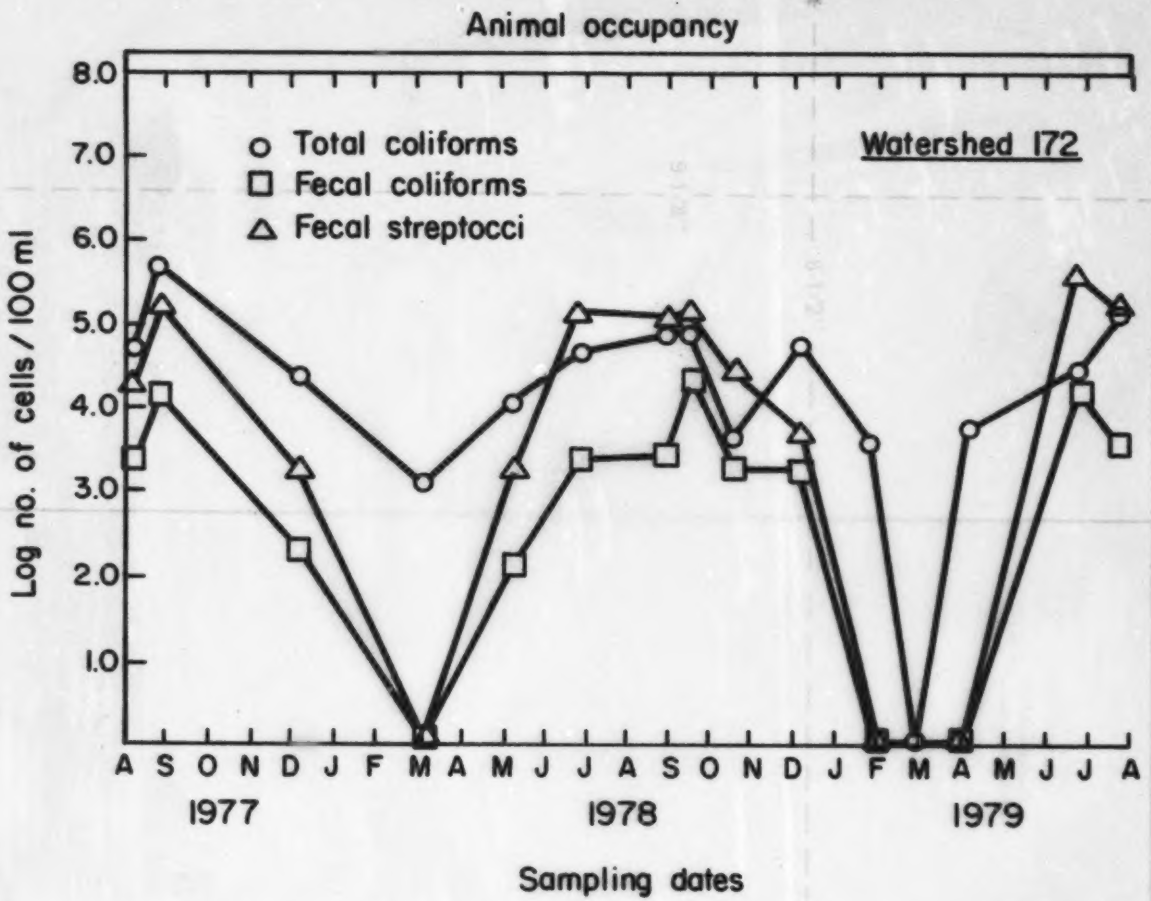

Figure 24. Numbers of TC, FC and FS in runoff water from WS 172 for the sampling dates indicated. Values are means of "beginning" runoff events and "end" runoff events.

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The numbers of all three indicator bacteria did not provide as clear a relationship to actual animal occupancy as might have been desired. However, it can be seen that the numbers of indicator bacteria in runoff from WS 129 (Figure 21) were consistantly higher than that of the other three watersheds (Figures 22-24). Of the three indicator groups TC showed the least variability between watersheds and over time (Figure 25). Similar results have been reported by Kunkle (1979) from runoff studies done with field applied dairy manure. The occurrence of nonfecal coliforms in runoff is not surprising since the soil and vegetation contains large numbers of bacteria which react biochemically as coliforms in the differential media employed (van Donsel et al., 1967). Fecal coliforms and FS generally were the most responsive groups of indicator bacteria, with slightly increased numbers in those watersheds with the greatest animal occupancy and with a population decline to zero during winter months on those watersheds with low levels of animal occupancy (Figure 26 and Figure 27). Doran and Linn (1979) have reported that cool air temperature (indirectly cool water temperatures) reduced the numbers of both FC and FS in pasture runoff samples. A second important aspect of the study is the confirmation of previous data (Doran and Linn, 1979) that the water quality of runoff waters from pasture watersheds, regardless of the presence of grazing cattle, frequently exceeds the water quality criterium for coliforms per 100 ml. WS 172 (no grazing cattle at all) exceeded this criterion 11 out of 15 sampling dates (73%) over the two-year period (Figure 24). WS 106 which had animals present only in the winter exceeded this criterion six out of 11 times (55%) and then primarily during the summer periods when cattle were not grazing on this watershed (Figure 22). The source of the FC and also FS in these two watersheds can be deduced from an evaluation of the FC/FS for all four watersheds (Table 13). WS 172 and 106 have mean FC/FS ratios of 0.07 and 0.01 respectively. These ratios are indicative of wildlife sources of fecal pollution (Geldreich, 1976, Doran and Linn, 1979). WS 129 and 110 had the greatest number of days of occupancy by cattle and had mean FC/FS ratios of 0.18 and 0.22 respectively. Geldreich (1976) had indicated that the expected FC/FS ratio for cattle was 0.177, while Doran and Linn (1979) found a mean value for the FC/FS ratio in runoff from pastureland over an entire year to be 0.26. Doran and Linn also concluded that ratios less than 0.05 were indicative of wildlife sources of fecal pollution while ratios greater than 0.1 were characteristic of grazing cattle. If these ratios hold, it can be seen that the source of fecal materials from rainfall events during the two years varied even for those watersheds with high grazing animal occupancy (Table 13).

The experimental design also provided the opportunity to evaluate numbers of indicator bacteria early in the runoff from a particular runoff event as well as during the latter stages of this event. These data are summarized in Table 14. Both TC and FC differed very little between the beginning and end of runoff events although mean numbers were generally lower toward the end of the event. Fecal streptococci differed and in general increased in the runoff samples from the end of the runoff event. Although we have no evidence to support our conclusions, this difference may mean a differential die-back of FS during the short time these samples were stored before they were transported to the laboratory.

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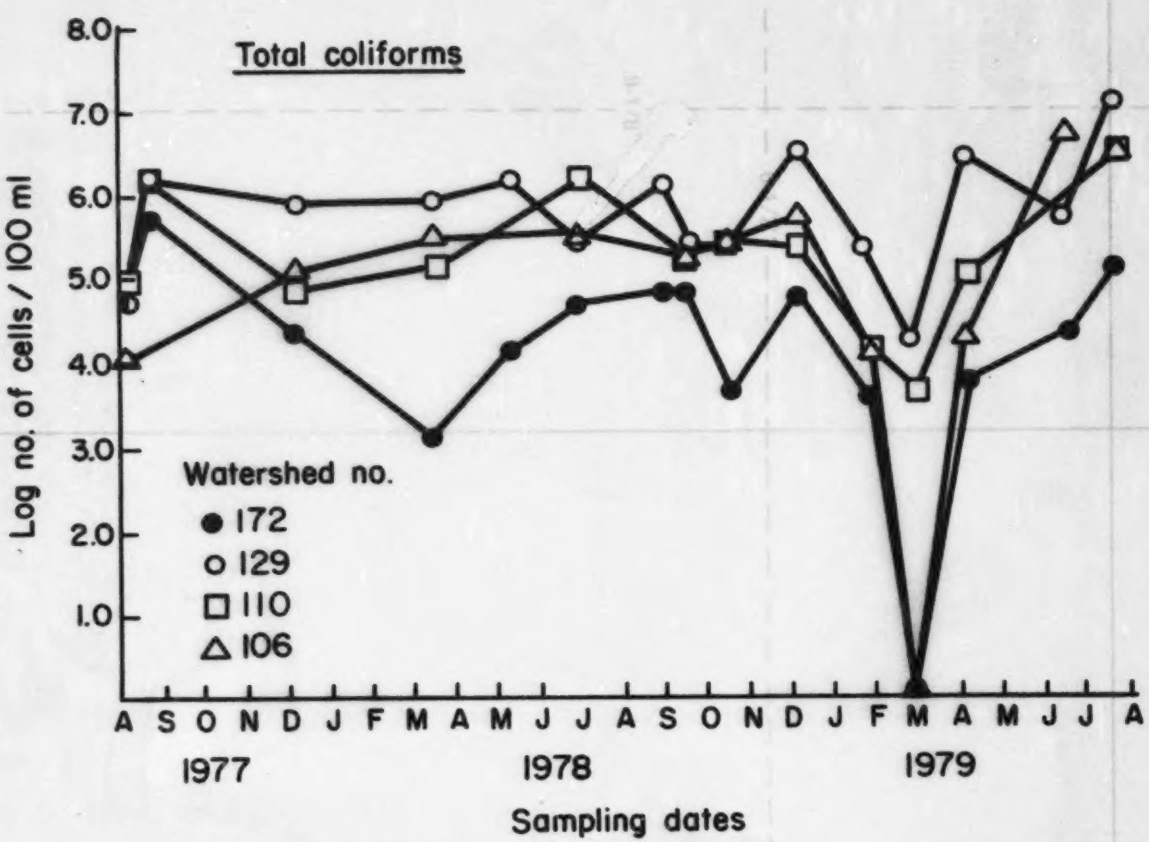

Figure 25. Comparison of numbers of TC in runoff water from each of four watersheds for the sampling dates indicated.

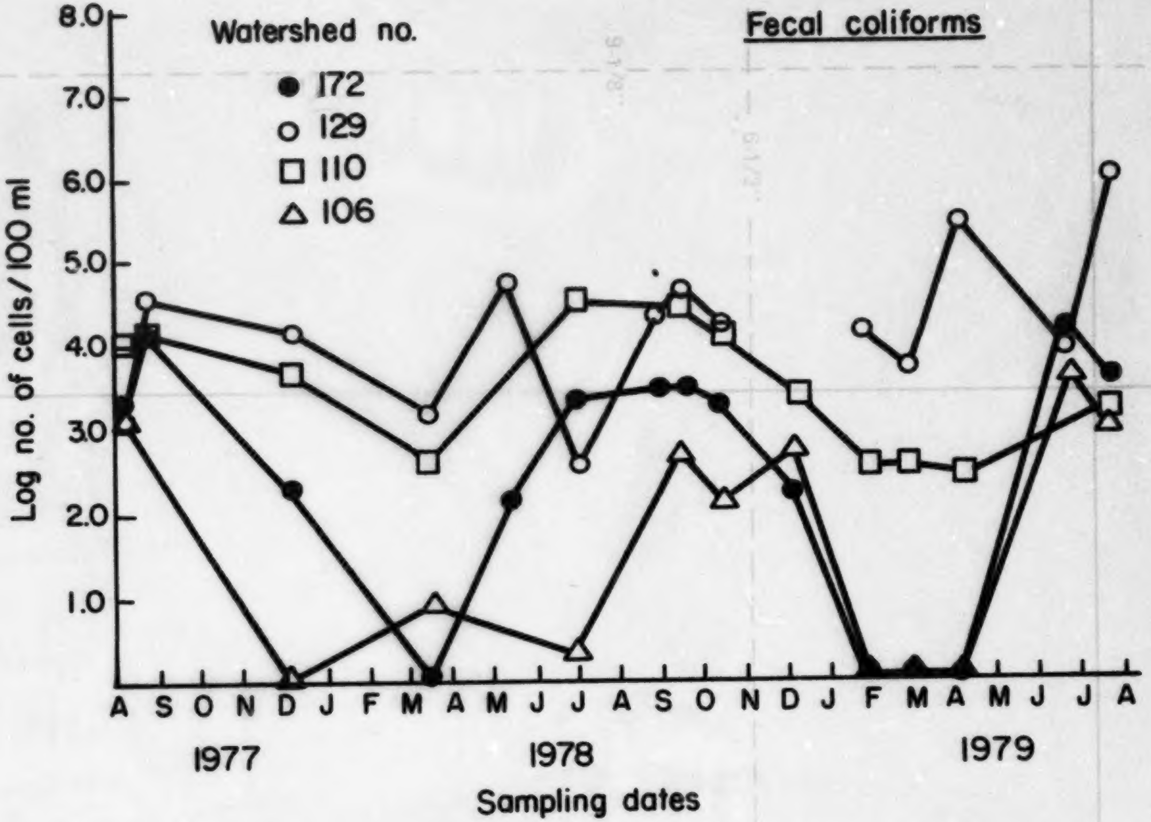

Figure 26. Comparison of numbers of FC in runoff water from each of four watersheds for the sampling dates indicated.

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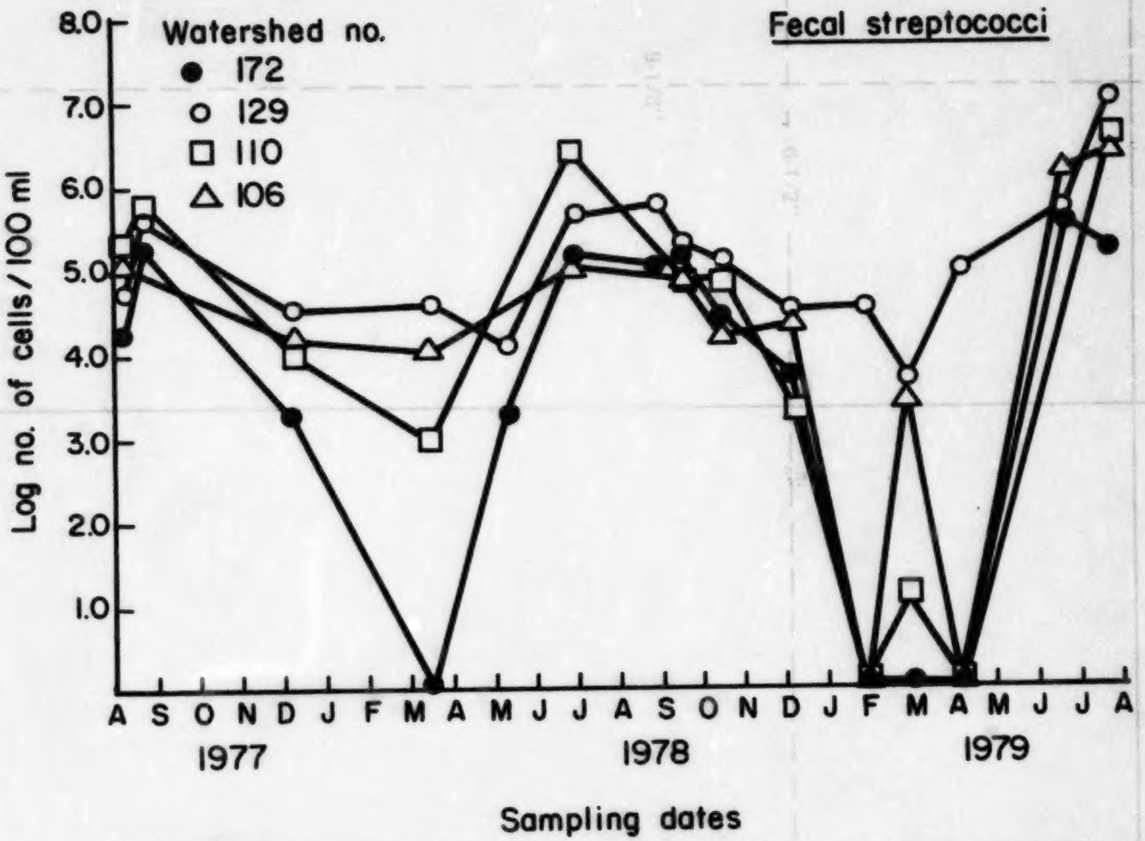

Figure 27. Comparison of numbers of FS in runoff water from each of four watersheds for the sampling dates indicated.

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TABLE 13. FECAL COLIFORM TO FECAL STREPTOCOCCUS RATIO (FC/FS) IN RUNOFF FROM EACH OF THE EXPERIMENTAL WATERSHEDS FOR THE SAMPLING DATES SHOWN

WS #	Sampling dates															Mean ratio
	1977			1978							1979					
	8/4	8/22	12/6	3/14	5/9	6/27	8/31	9/15	10/13	12/4	1/25	2/26	4/5	6/21	7/23	
172	.13	.09	.10	--	.07	.02	.02	.16	.08	.04	--	--	--	.04	.02	0.07
129	.01	.11	.52	.06	.49	.03	.04	.25	.12	--	.39	.08	.25	.02	.09	0.18
110	.05	.03	.51	.30	--	.02	--	.38	.18	.40	--	.13	--	--	.19	0.22
106	.01	--	<.001	.01	--	<.001	--	.07	.008	.23	--	--	--	.003	.001	0.01

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TABLE 14. NUMBERS OF CELLS OF EACH GROUP OF INDICATOR BACTERIA AT THE BEGINNING AND END OF EACH RUNOFF EVENT. THE VALUES ARE MEANS OF ALL RUNOFF EVENTS DURING THE STUDY PERIOD.

Watershed	TC		FC		FS	
	Log no. of cells/100 ml					
106 beginning	5.18	N=10*	2.56	N= 7	4.48	N=10
end	5.17		2.54		4.76	
110 beginning	5.18	N=10	3.47	N=10	3.76	N= 8
end	5.15		3.30		4.47	
129 beginning	6.38	N=10	4.04	N= 9	5.07	N=15
end	5.70		3.90		5.08	

*N = number of runoff event contribution to the mean.

In summary, these data are almost in complete agreement with those of a similar study by Doran and Linn (1979) and Doran et al., (1981) and support their conclusions that recommended bacteriological water quality criteria may be inappropriate for characterizing pasture runoff and other nonpoint sources of potential pollution.

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APPENDIX A

PRECIPITATION AND RUNOFF GRAPHS FOR WS 106, WS 110 AND WS 129

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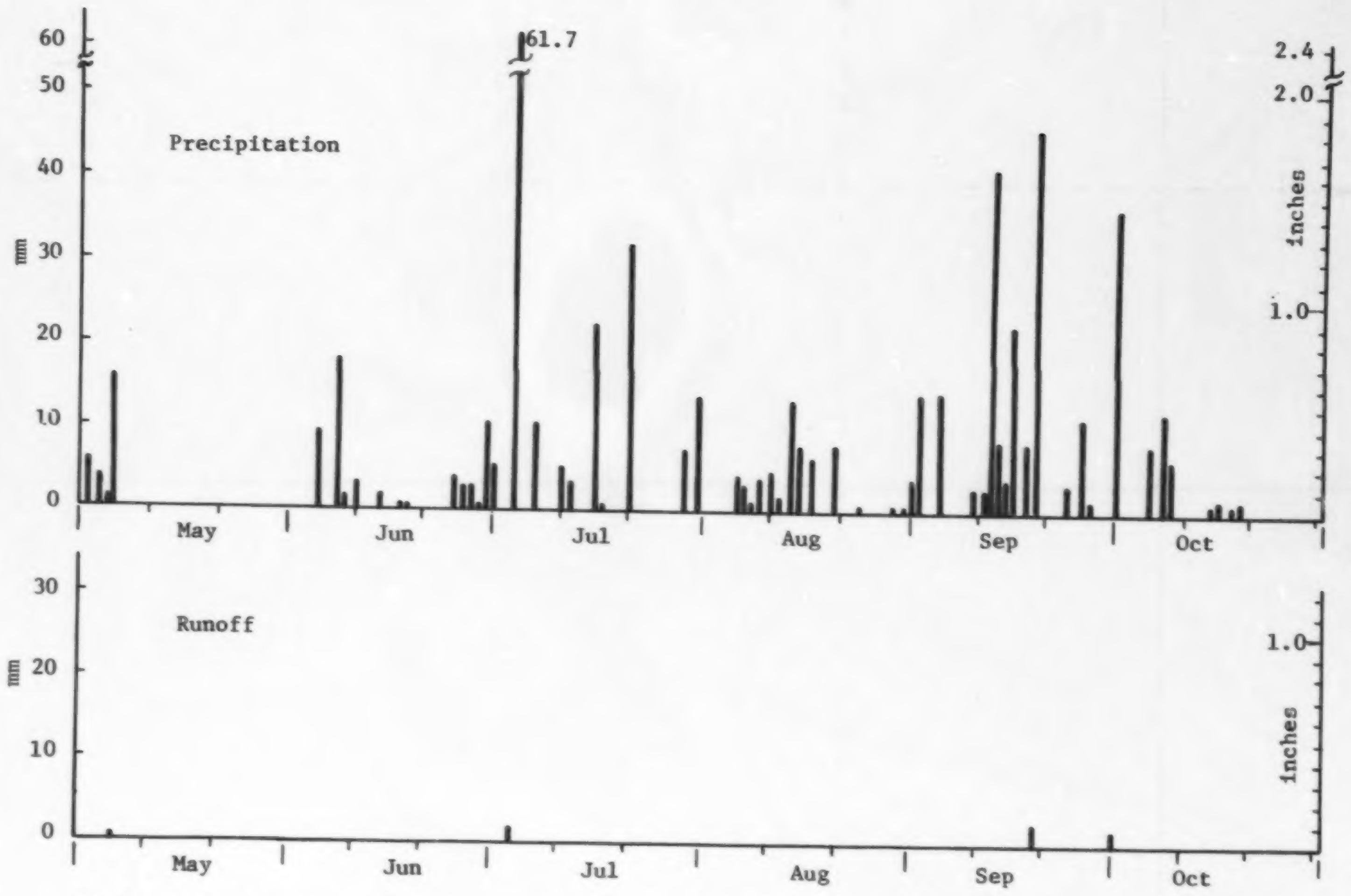

Figure A-1. Precipitation and runoff on WS 106 for growing season, 1977.

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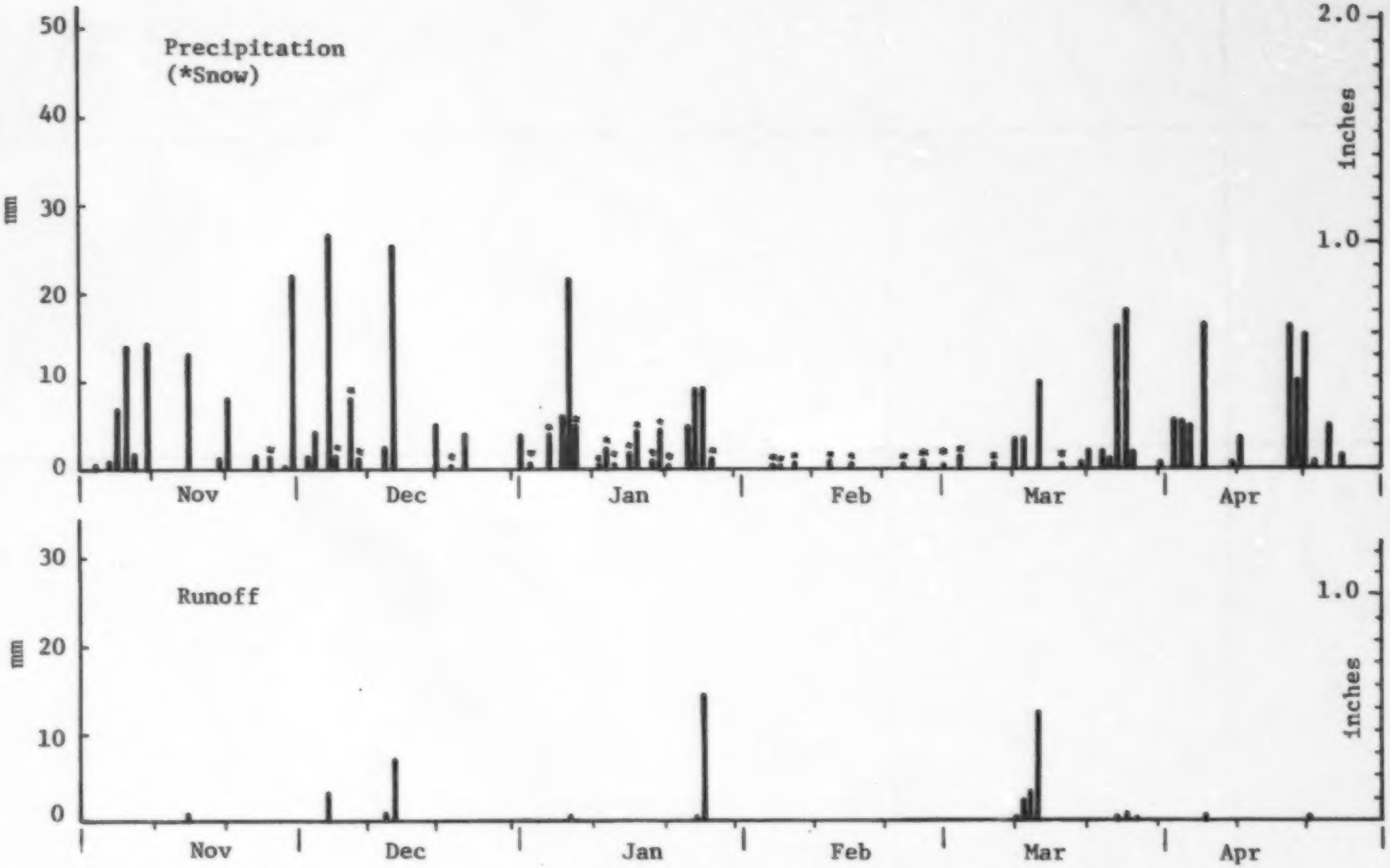

Figure A-2. Precipitation and runoff on WS 106 for dormant season, 1977-78.

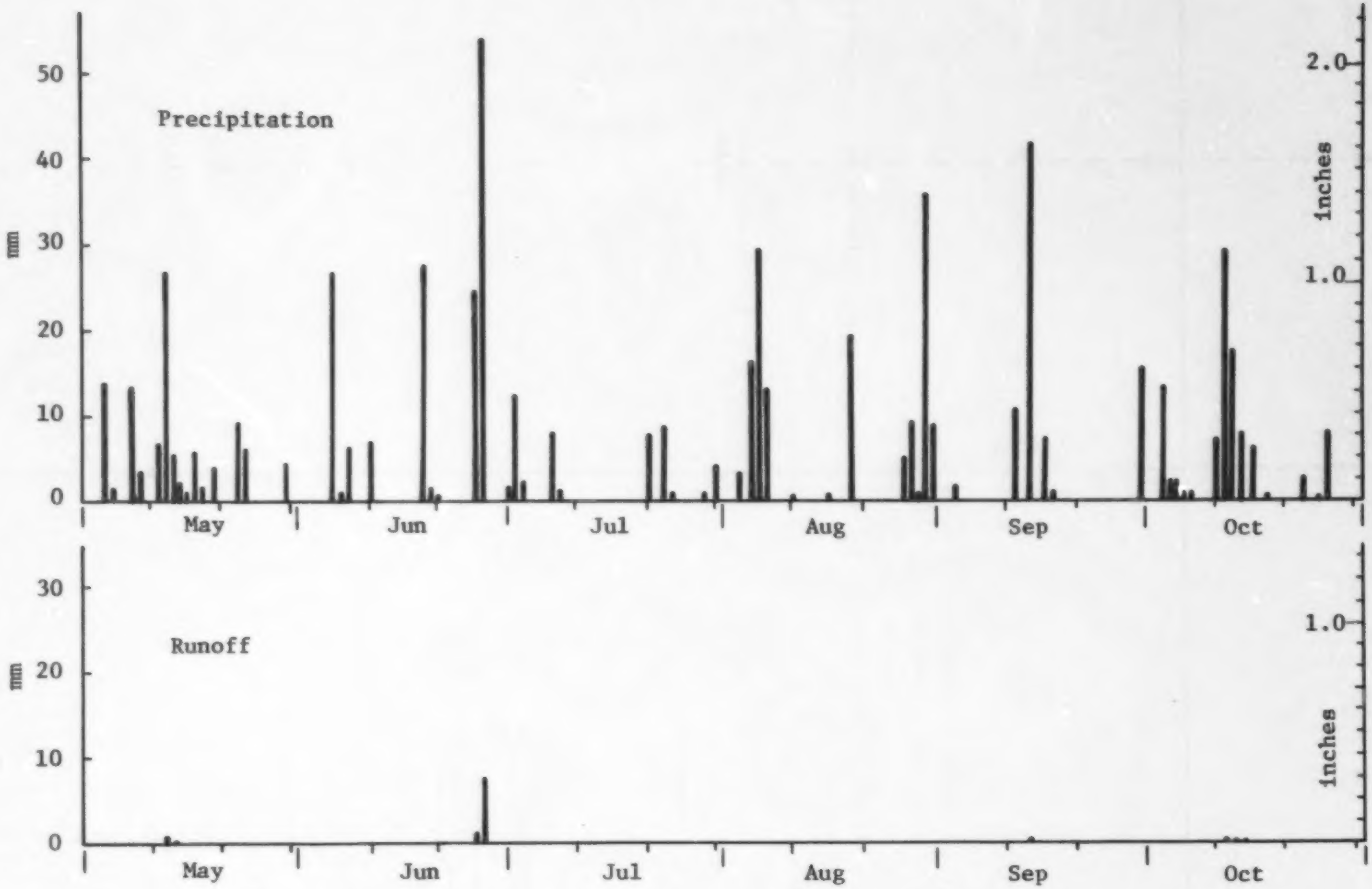

Figure A-3. Precipitation and runoff on WS 106 for growing season, 1978.

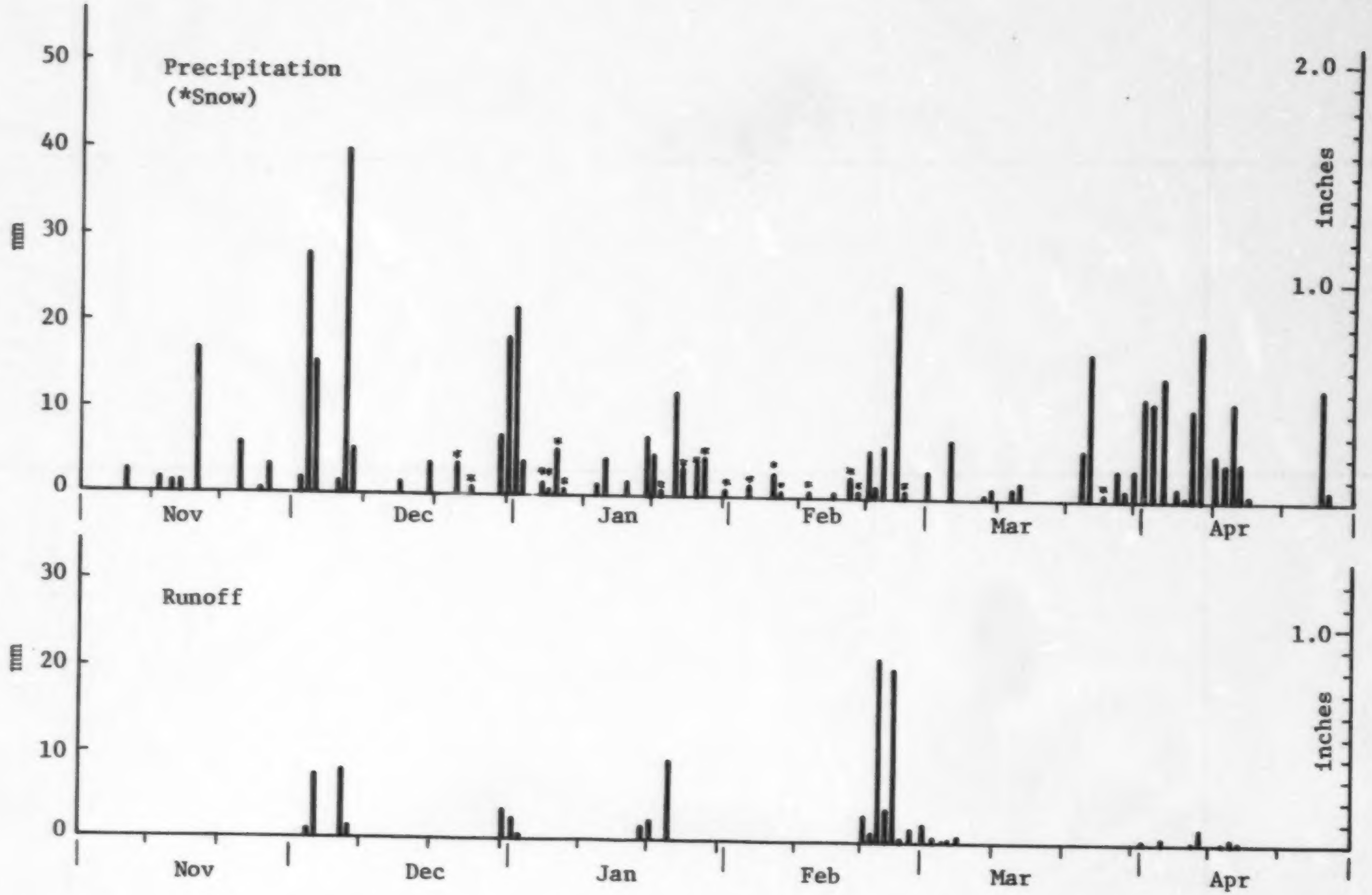

Figure A-4. Precipitation and runoff on WS 106 for dormant season, 1978-79.

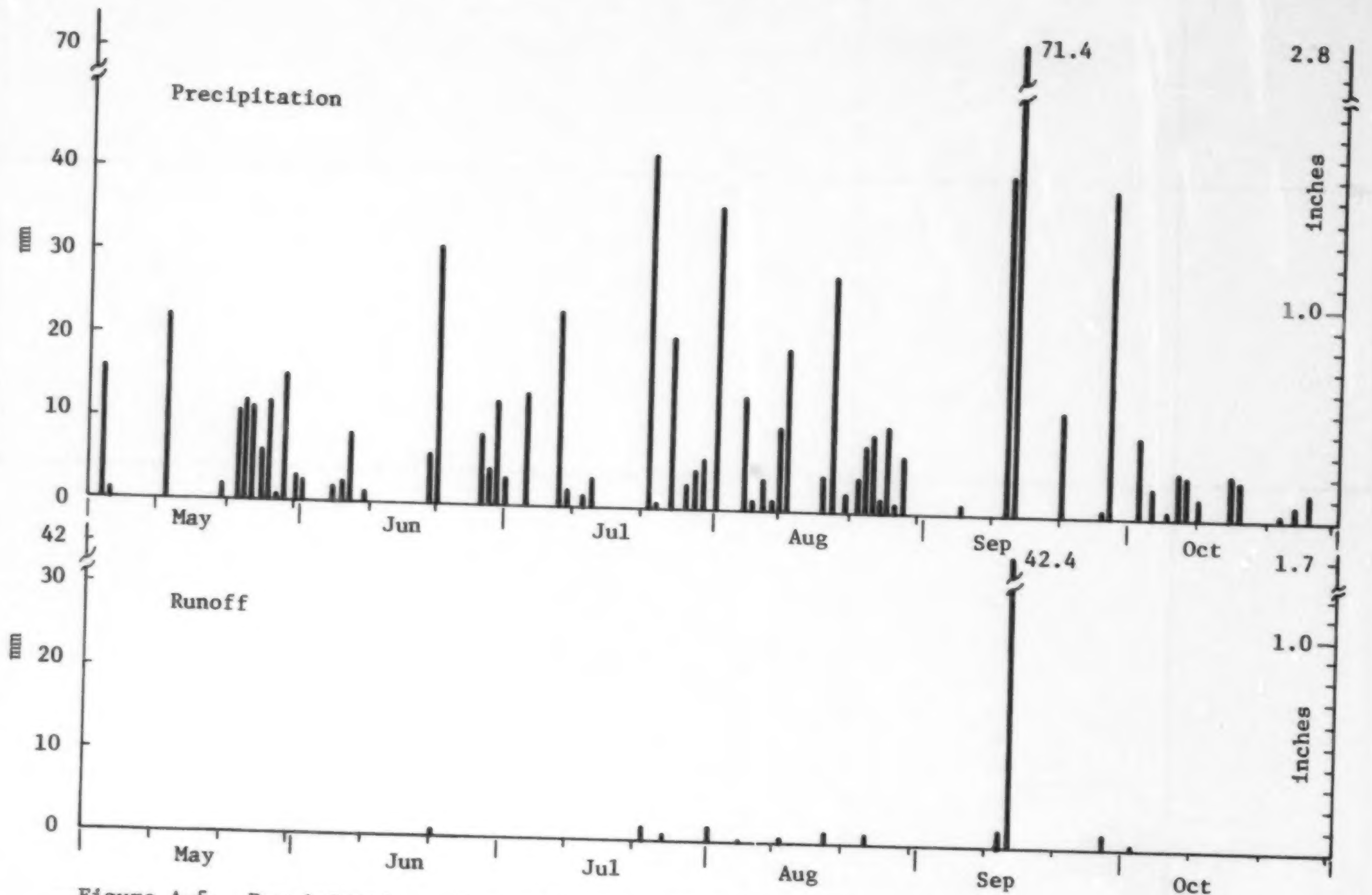

Figure A-5. Precipitation and runoff on WS 106 for growing season, 1978-79.

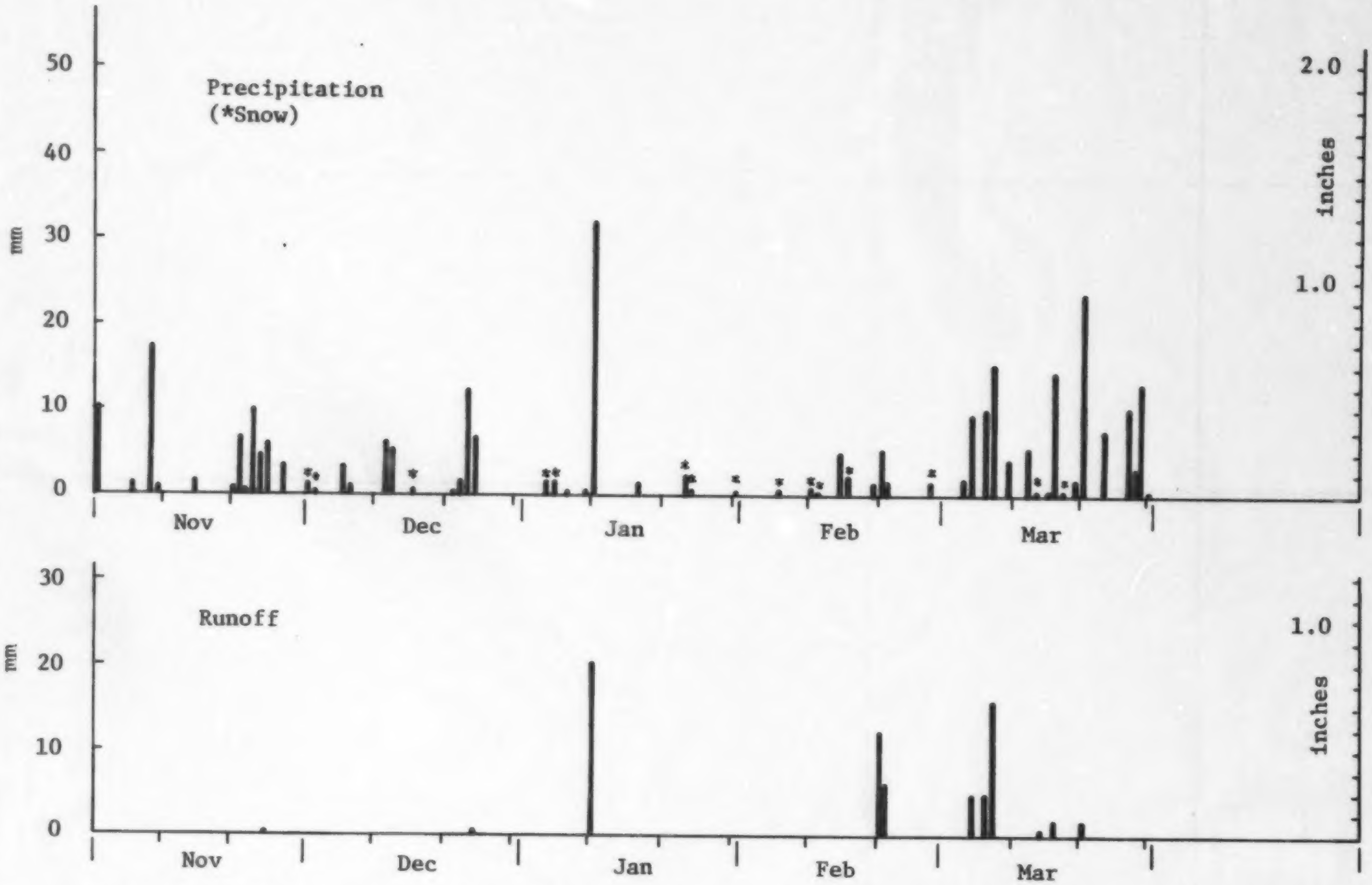

Figure A-6. Precipitation and runoff on WS 106 for dormant season, 1979-80.

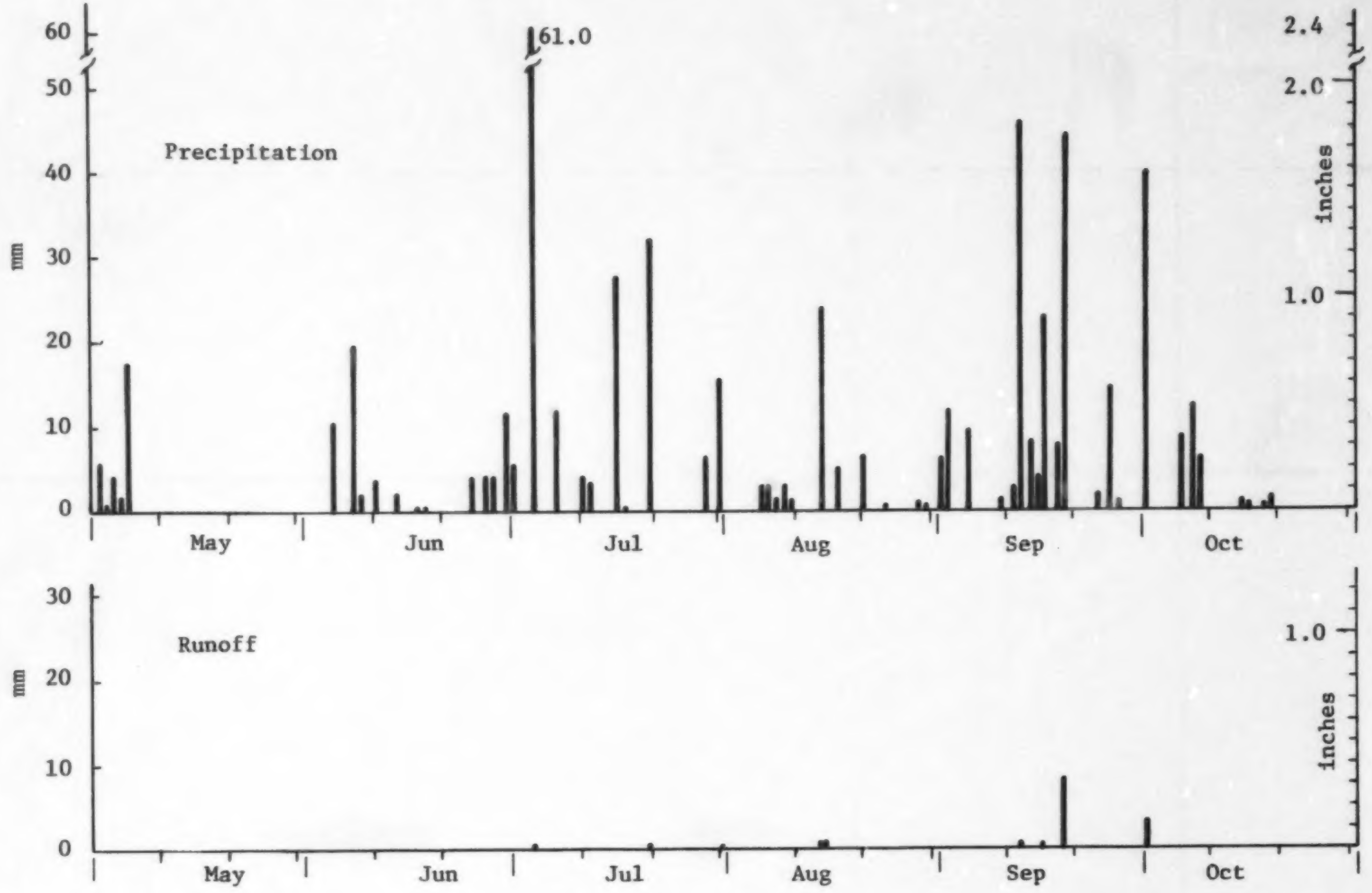

Figure A-7. Precipitation and runoff on WS 110 for growing season, 1977.

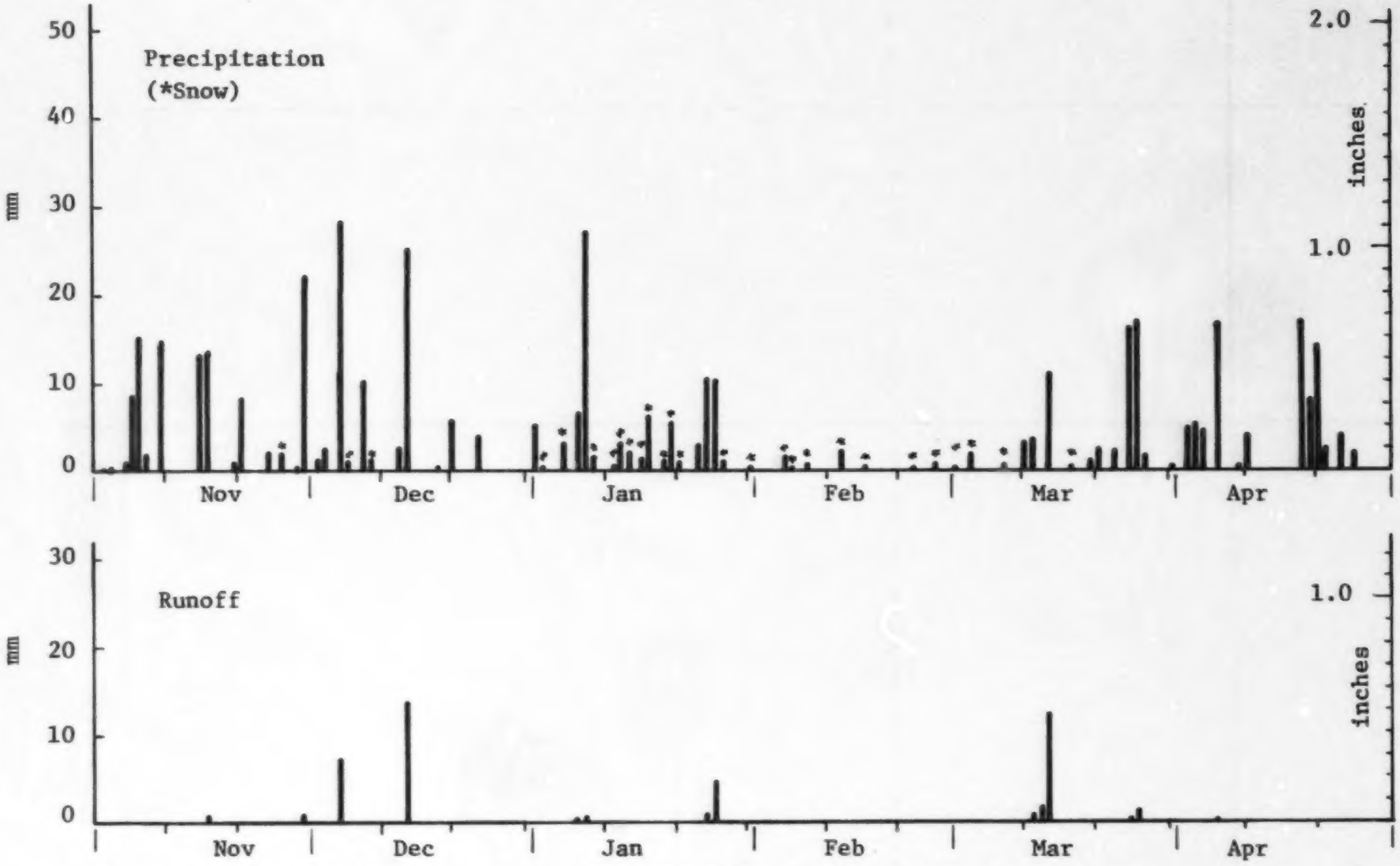

Figure A-8. Precipitation and runoff on WS 110 for dormant season, 1977-79.

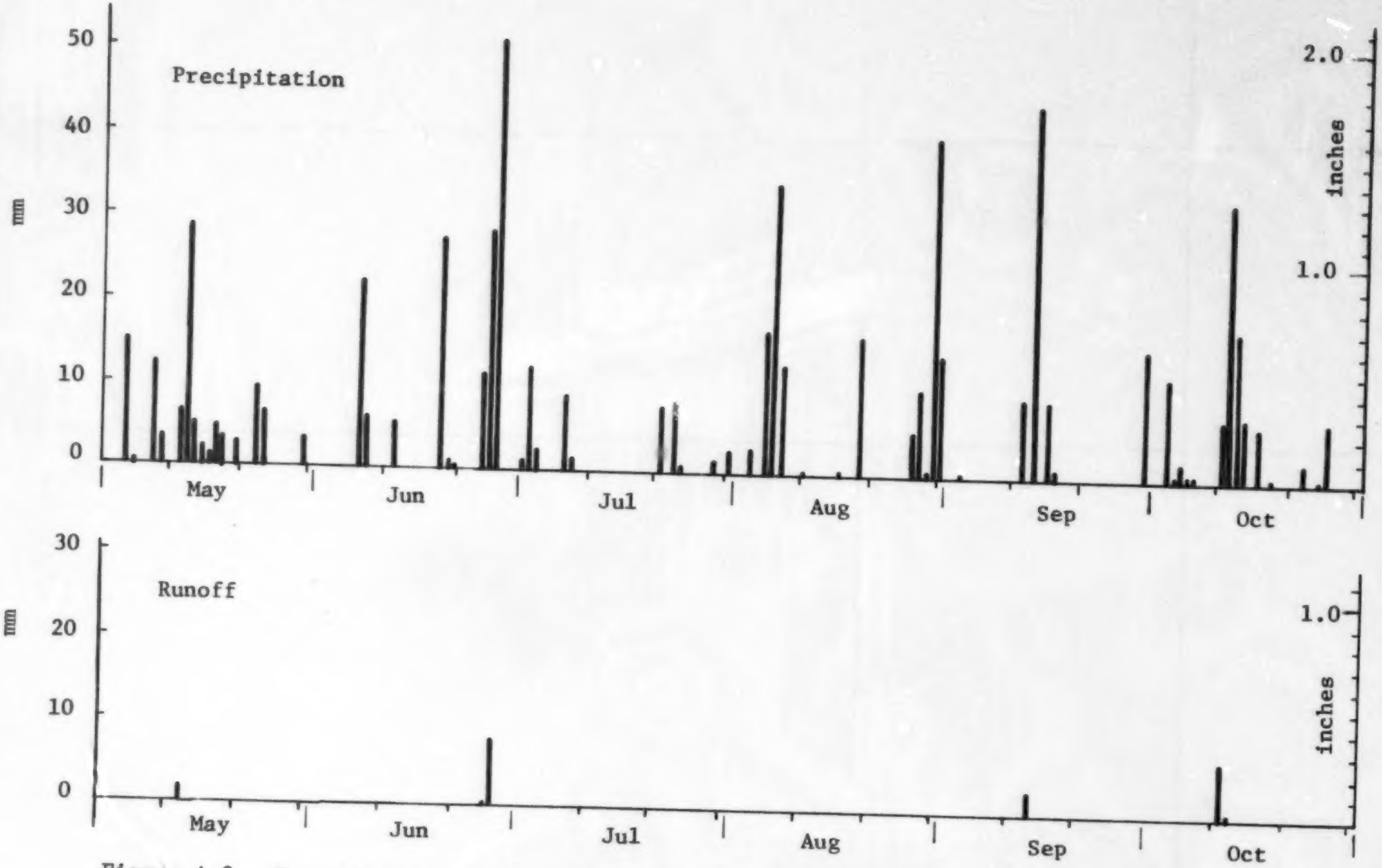

Figure A-9. Precipitation and runoff on WS 110 for growing season, 1978.

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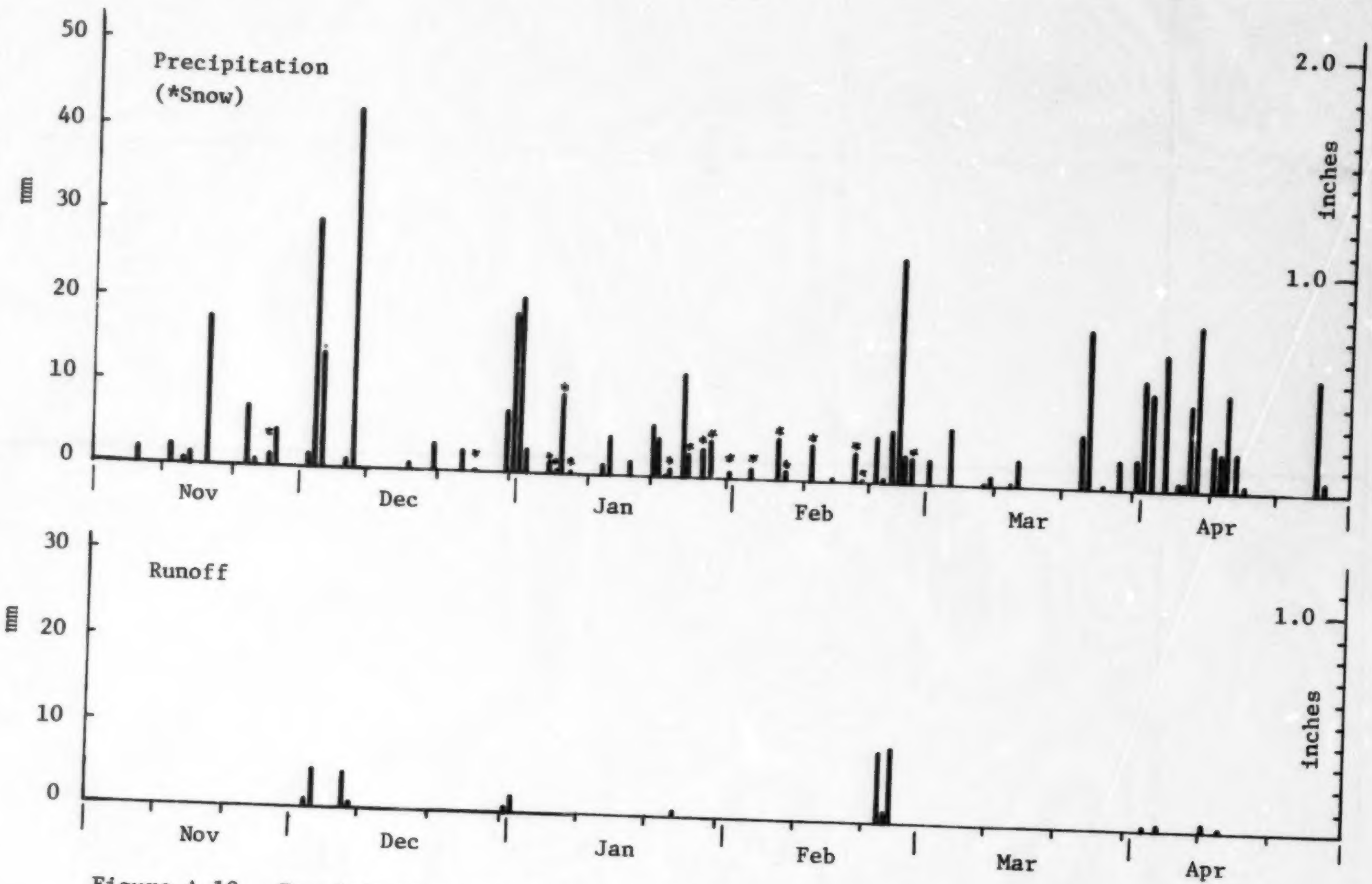

Figure A-10. Precipitation and runoff on WS 110 for dormant season, 1978-79.

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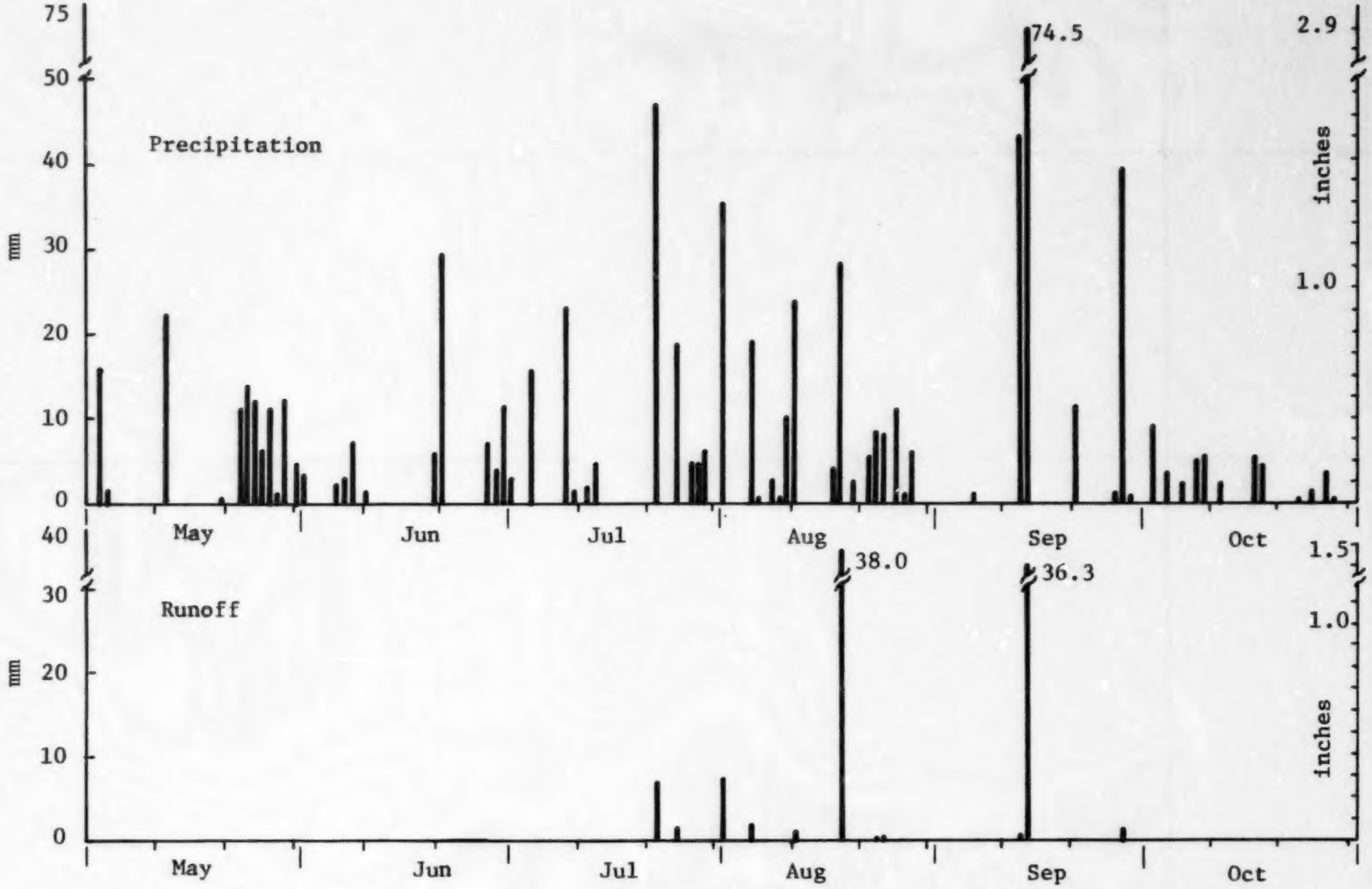

Figure A-11. Precipitation and runoff on WS 110 for growing season, 1979.

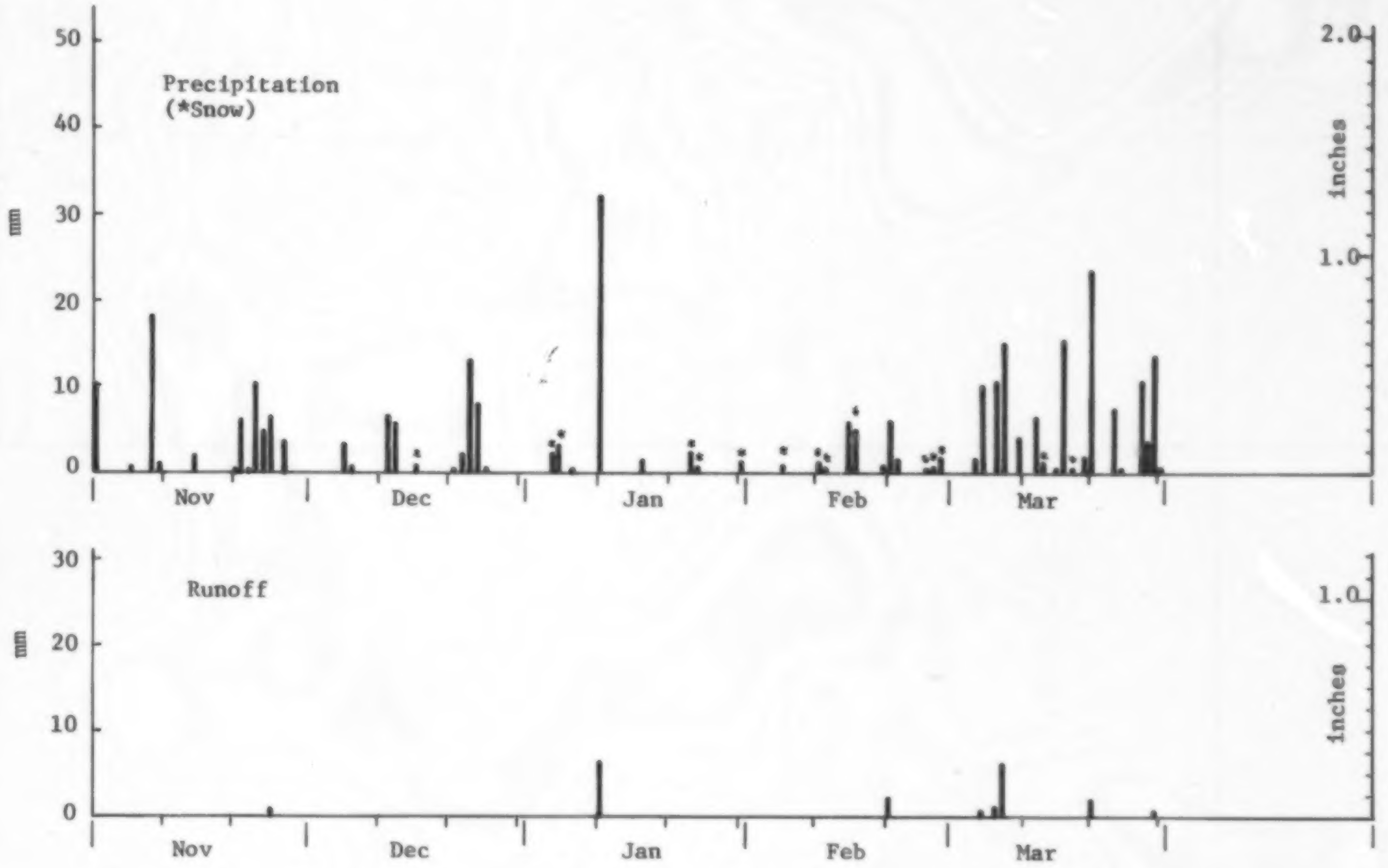

Figure A-12. Precipitation and runoff on WS 110 for dormant season, 1979-80.

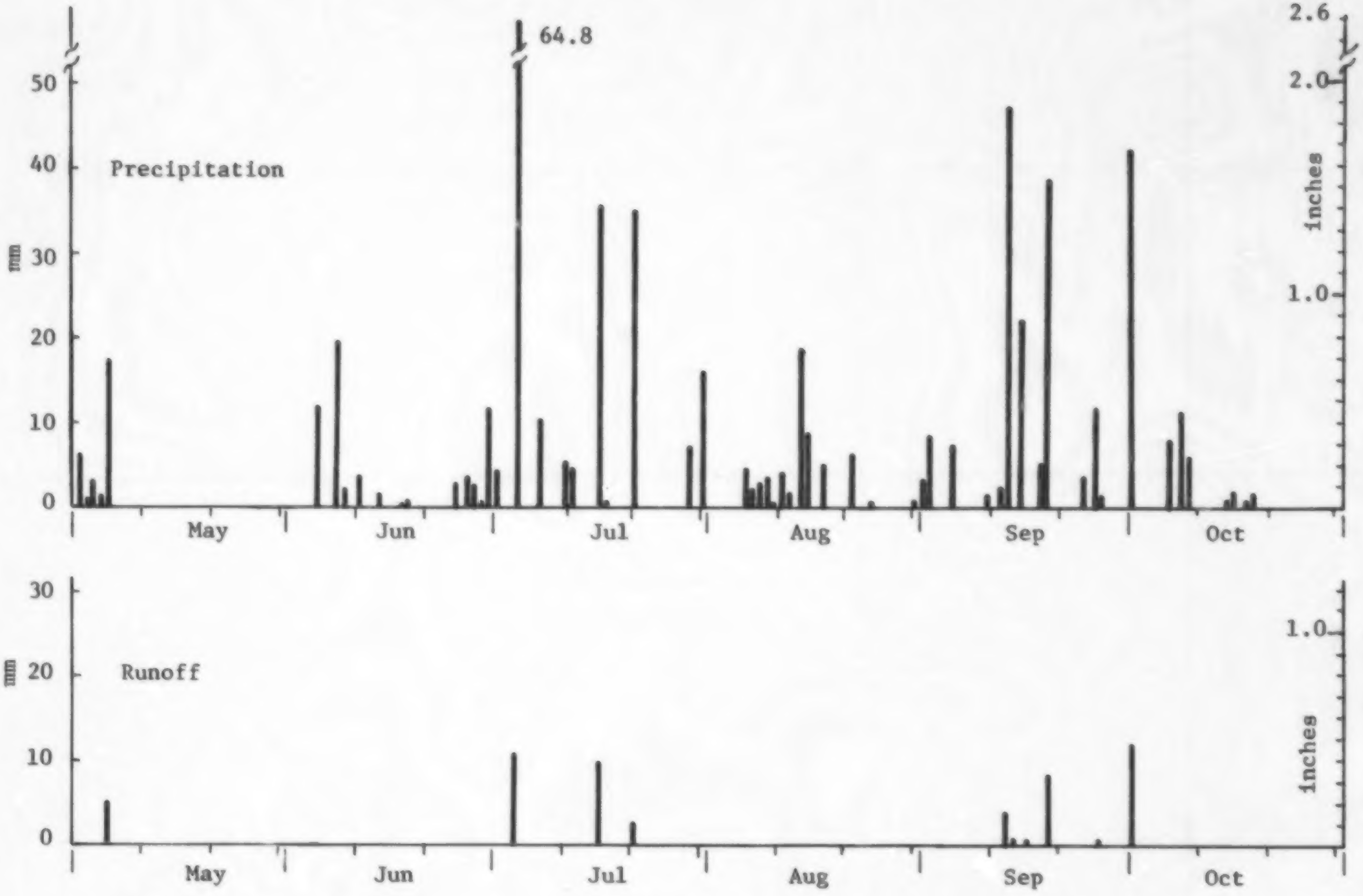

Figure A-13. Precipitation and runoff on WS 129 for growing season, 1977.

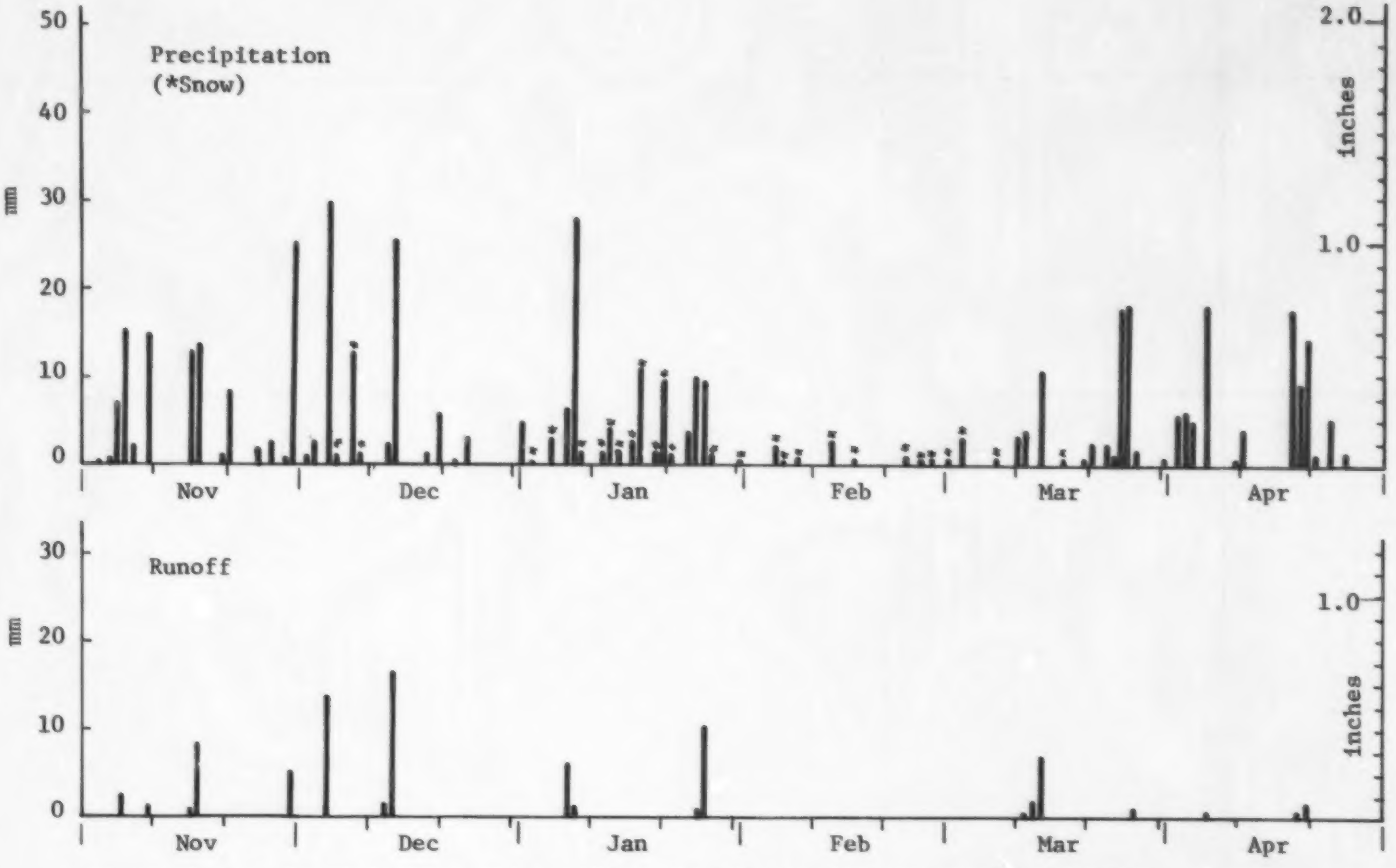

Figure A-14. Precipitation and runoff on WS 129 for dormant season, 1977-78.

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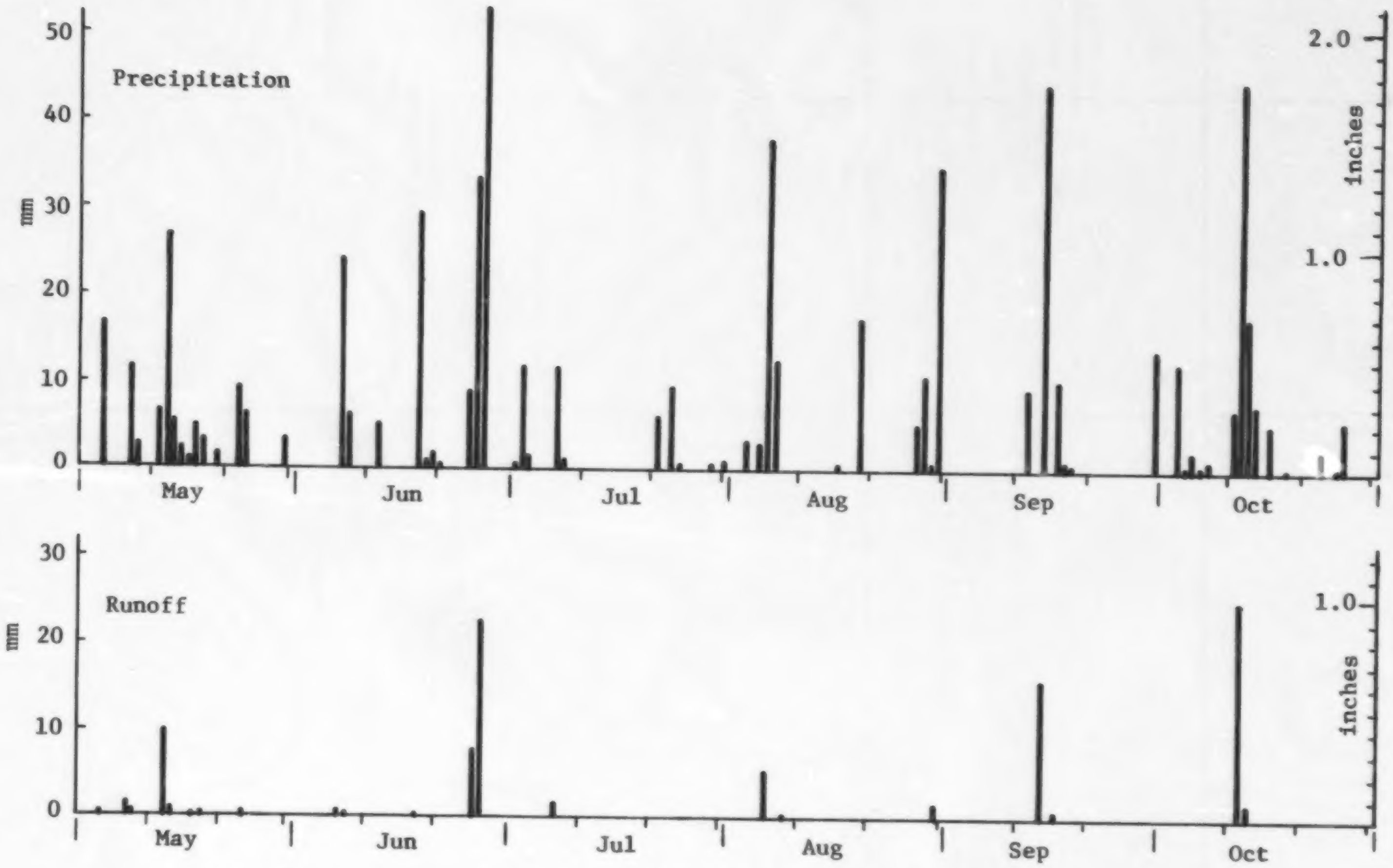

Figure A-15. Precipitation and runoff on WS 129 for growing season, 1978.

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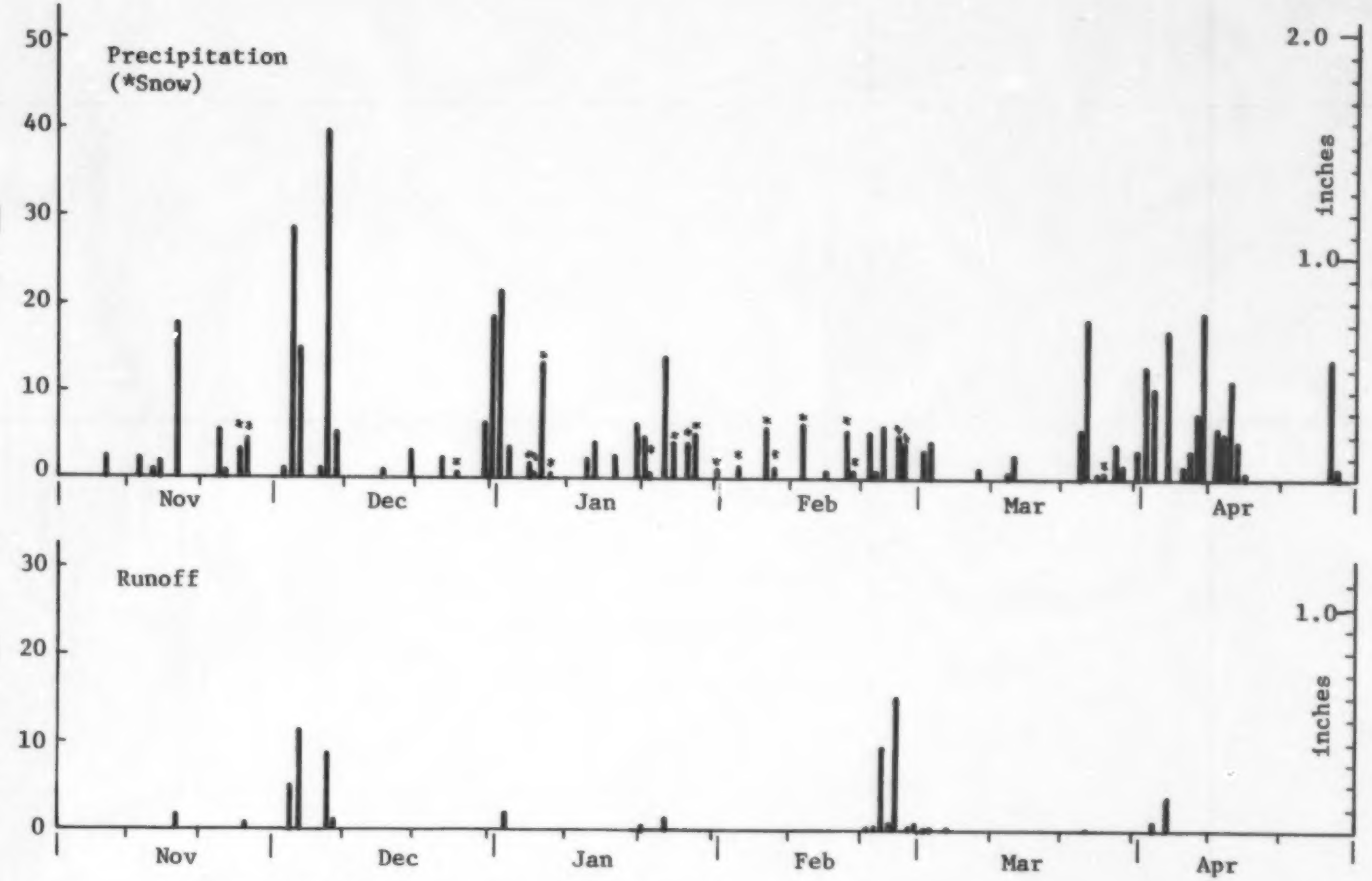

Figure A-16. Precipitation and runoff on WS 129 for dormant season, 1978-79.

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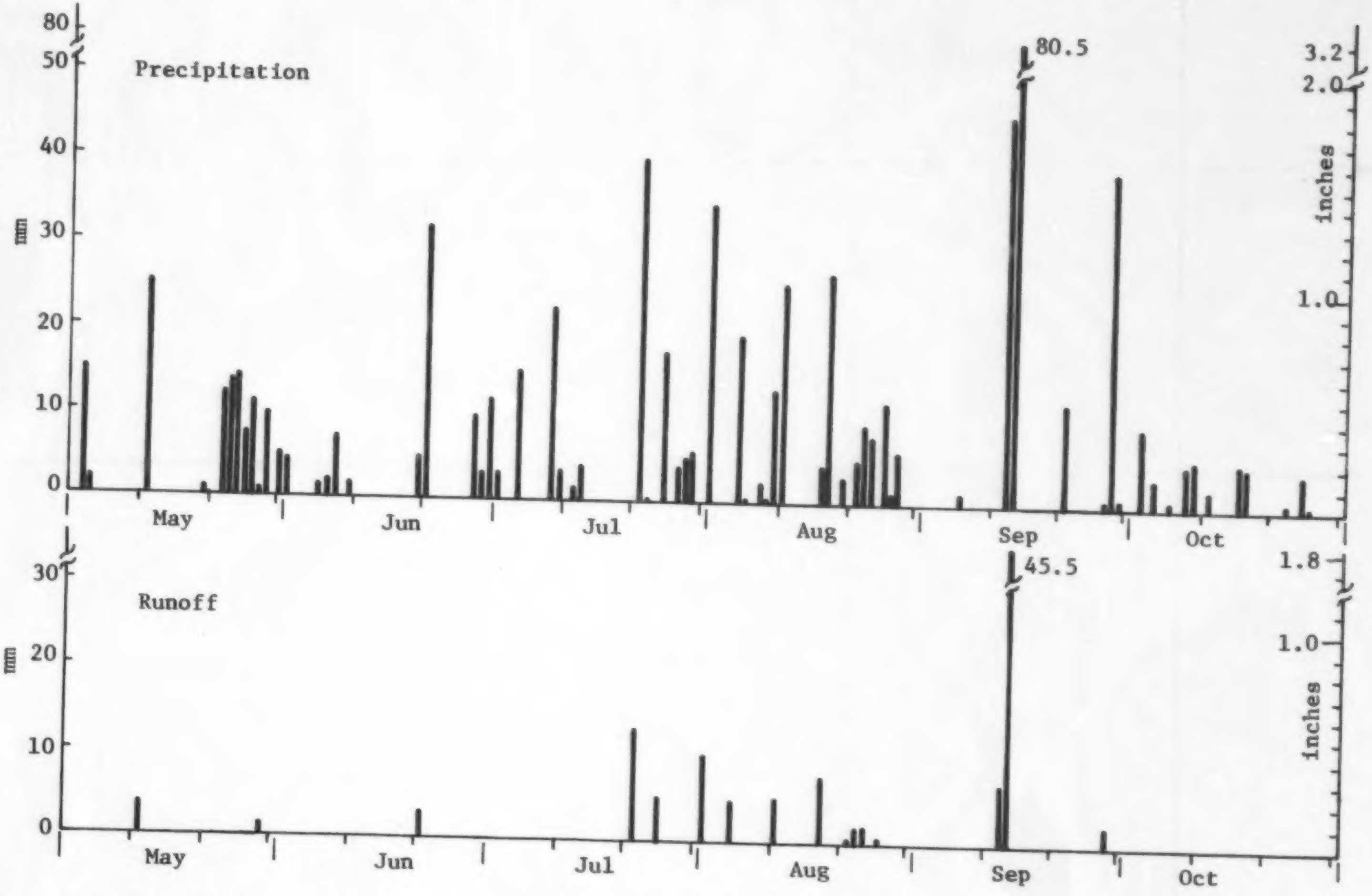

Figure A-17. Precipitation and runoff on WS 129 for growing season, 1979.

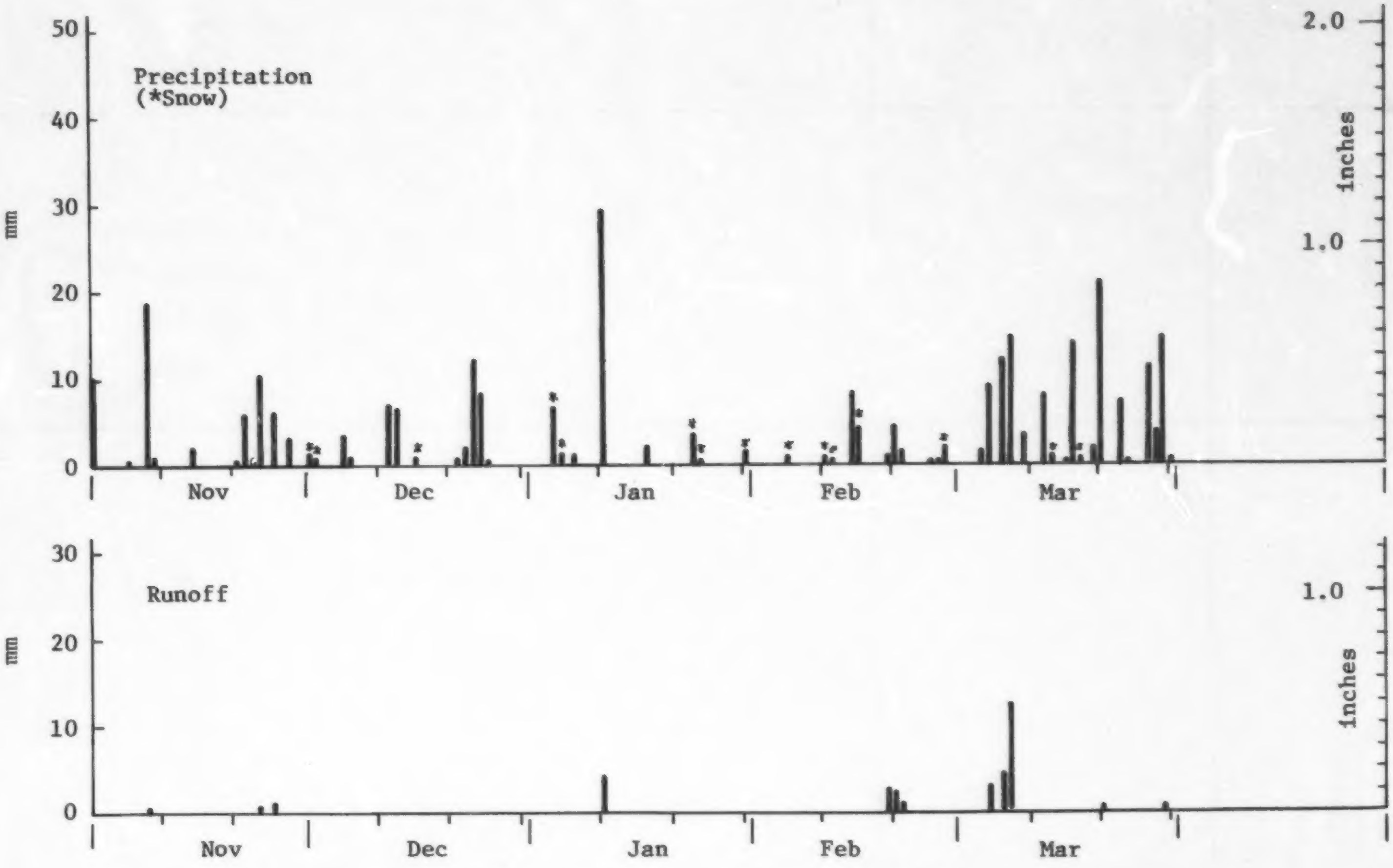

Figure A-18. Precipitation and runoff on WS 129 for dormant season, 1979-80.

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APPENDIX B

LIVESTOCK OCCUPANCY ON WATERSHEDS

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TABLE B-1. LIVESTOCK OCCUPANCY ON WS 106 (AREA E4)

Time period	Cattle occupancy	Number of animals
10/6/76 to 2/11/77	Off	
2/11 to 3/21	On 28 days	40 cows
3/21 to 12/23	Off	
12/23/77 to 1/22/78	On 30 days	40 cows
1/22 to 11/21	Off	
11/21 to 12/23	On 32 days	35 cows
12/23/78 to 11/27/79	Off	
11/27/79 to 1/1/80	On 35 days	35 cows
1/1 to 3/15	Off	

TABLE B-2. LIVESTOCK OCCUPANCY ON WS 110 (AREA D2)

Time period	Cattle occupancy	Number of animals
10/6/76 to 4/18/77	Off	
4/18 to 4/21	On 3 days	39 cows, 37 calves
4/21 to 5/2	Off	
5/2 to 5/10	On 8 days	40 cows, 37 calves
5/10 to 5/17	Off	
5/17 to 5/18	On 1 day	40 cows, 37 calves
5/18 to 5/26	Off	
5/26 to 5/27	On 1 day	40 cows, 37 calves
5/27 to 5/31	Off	
5/31 to 6/7	On 7 days	40 cows, 37 calves
6/7 to 6/20	Off	
6/20 to 6/26	On 6 days	40 cows, 37 calves
6/26 to 7/26	Off	
7/26 to 8/1	On 6 days	40 cows, 37 calves
8/1 to 8/12	Off	
8/12 to 8/16	On 4 days	40 cows, 37 calves
8/16 to 8/23	Off	
8/23 to 8/26	On 3 days	40 cows, 37 calves
8/26 to 9/2	Off	
9/2 to 9/6	On 4 days	40 cows, 37 calves
9/6 to 1/12	Off	
9/12 to 9/13	On 1 day	40 cows, 37 calves
9/13 to 10/5	Off	

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TABLE B-2 (continued)

Time period	Cattle occupancy	Number of animals
10/5 to 10/8	On 3 days	40 cows, 37 calves
10/8/77 to 4/28/78	Off	
4/28 to 5/1	On 3 days	40 cows, 35 calves
5/1 to 5/15	Off	
5/15 to 5/19	On 4 days	40 cows, 35 calves
5/19 to 6/5	Off	
6/5 to 6/9	On 4 days	40 cows, 35 calves
6/9 to 7/18	Off	
7/18 to 7/25	On 7 days	40 cows, 35 calves
7/25 to 8/9	Off	
8/9 to 8/13	On 4 days	40 cows, 35 calves
8/13 to 8/29	Off	
8/29 to 9/4	On 6 days	40 cows, 35 calves
9/4 to 9/25	Off	
9/25 to 10/2	On 7 days	35 cows, 35 calves
10/2/78 to 4/26/79	Off	
4/26 to 4/30	On 4 days	37 cows, 33 calves
4/30 to 5/14	Off	
5/14 to 5/18	On 4 days	35 cows, 35 calves
5/18 to 6/1	Off	
6/1 to 6/7	On 6 days	35 cows, 35 calves
6/7 to 6/18	Off	
6/18 to 6/22	On 4 days	35 cows, 35 calves
6/22 to 7/6	Off	
7/6 to 7/13	On 7 days	35 cows, 35 calves
7/13 to 7/27	Off	
7/27 to 7/30	On 3 days	35 cows, 35 calves
7/30 to 8/13	Off	
8/13 to 8/17	On 4 days	35 cows, 35 calves
8/17 to 9/17	Off	
9/17 to 9/23	On 6 days	35 cows, 35 calves
9/23 to 10/14	Off	
10/14 to 10/19	On 5 days	35 cows
10/19/79 to 3/15/80	Off	

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TABLE B-3. LIVESTOCK OCCUPANCY ON WS 129 (AREA B1)

Time period	Cattle occupancy	Number of animals
11/6/76 to 4/21/77	On 166 days	25 cows, 25 calves
4/21 to 5/27	Off	
5/27 to 6/3	On 7 days	25 cows, 25 calves
6/3 to 7/5	Off	
7/5 to 7/15	On 10 days	25 cows, 25 calves
7/15 to 8/12	Off	
8/12 to 8/23	On 11 days	25 cows, 25 calves
8/23 to 10/13	Off	
10/13 to 10/26	On 13 days	25 cows
10/26/77 to 5/1/78	On 186 days	25 cows, 25 calves
5/1 to 6/9	Off	
6/9 to 6/13	On 4 days	25 cows, 20 calves
6/13 to 6/26	Off	
6/26 to 7/3	On 8 days	25 cows, 20 calves
7/3 to 7/23	Off	
7/23 to 8/3	On 11 days	25 cows, 20 calves
8/3 to 8/25	Off	
8/25 to 9/5	On 11 days	25 cows, 20 calves
9/5 to 10/2	Off	
10/2 to 10/6	On 4 days	25 cows, 20 calves
10/6 to 10/19	Off	
10/19 to 10/20	On 1 day	15 cows
10/20 to 10/27	Off	
10/27/78 to 2/8/79	On	25 cows
2/8 to 3/9	On 182 days	17 cows
3/9 to 4/27	On	25 cows with calves
4/27 to 6/6	Off	
6/6 to 6/8	On 2 days	25 cows, 25 calves
6/8 to 7/13	Off	
7/13 to 7/23	On 10 days	25 cows, 25 calves
7/23 to 8/14	Off	
8/14 to 8/22	On 8 days	25 cows, 24 calves
8/22 to 9/12	Off	
9/15 to 9/17	On 2 days	9 bulls
9/17 to 10/25	Off	
10/25 to 10/26	On 1 day	6 cows
10/26 to 11/7	Off	
11/7/79 to 4/25/80	On 150 days	25 cows, (winter feeding)

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APPENDIX C

RUNOFF EVENTS SELECTED FOR PERIODIC ANALYSIS

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TABLE C-1. DATA ON RUNOFF EVENTS FROM WATERSHED 106 SELECTED FOR PERIODIC ANALYSIS*

Date	Season#	Event size **	Runoff event time		Number of samples	Type of runoff##
			Start	Stop		
2/12/77	Dormant	Small	1536	3130	15	Snowmelt
2/22/77	Dormant	Large	1309	5655	21	Snowmelt
2/24/77	Dormant	Small	0859	1808	17	Rainfall
3/12/77	Dormant	Small	1137	3300	15	Rainfall
3/18/77	Dormant	Small	0310	1145	12	Rainfall
4/2/77	Dormant	Small	0640	2230	15	Rainfall
4/4/77	Dormant	Small	1737	2400	6	Rainfall
7/4/77	Growing	Small	0814	0955	15	Rainfall
9/19/77	Growing	Small	0648	2500	5	Rainfall
12/5/77	Dormant	Small	1552	2115	6	Snowmelt
12/13/77	Dormant	Large	0910	6005	6	Snowmelt
1/25/78	Dormant	Large	2103	3330	6	Snowmelt
3/13/78	Dormant	Large	1416	4800	10	Snowmelt
6/27/78	Growing	Large	1846	2400	5	Rainfall
12/3/78	Dormant	Large	0735	3334	5	Rainfall
12/8/78	Dormant	Large	0200	3120	7	Rainfall
12/31/78	Dormant	Small	1255	2854	6	Snowmelt
1/24/79	Dormant	Large	0724	1938	7	Snowmelt
2/21/79	Dormant	Small	0950	3600	6	Snowmelt
2/22/79	Dormant	Large	1454	7200	9	Snowmelt
4/9/79	Dormant	Small	0106	1650	5	Rainfall
6/21/79	Growing	Small	0449	0629	7	Rainfall
8/1/79	Growing	Small	1917	2640	10	Rainfall
8/17/79	Growing	Small	2250	3510	5	Rainfall
1/11/80	Dormant	Large	0510	2131	17	Rainfall
3/5/80	Dormant	Small	0345	2445	13	Rainfall
3/7/80	Dormant	Large	1345	4044	16	Rainfall

*Runoff events were selected for periodic analysis if there were at least five discrete samples within an event and if the runoff was initiated by rainfall.

#Dormant season is November through April. Growing season is May through October.

**Large runoff events were those with the equivalent of ≥ 0.75 cm of water over the experimental watershed. Small events have < 0.75 cm of water.

##All selected runoff events were initiated by rainfall, but when there was snow cover on the watershed, the temperature was near freezing and the total runoff appeared larger than would be expected by rainfall alone, then that event contained rainfall and snowmelt in the runoff and was listed as snowmelt.

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TABLE C-2. DATA ON RUNOFF EVENTS FROM WATERSHED 110 SELECTED FOR PERIODIC ANALYSIS*

Date	Season #	Event size **	Runoff event time		Number of samples	Type of runoff ##
			Start	Stop		
4/2/77	Dormant	Small	0720	2400	9	Rainfall
9/19/77	Growing	Large	0600	2345	10	Rainfall
10/1/77	Growing	Small	0630	0938	6	Rainfall
11/17/77	Dormant	Small	0002	0158	5	Rainfall
12/5/77	Dormant	Large	0629	1942	7	Snowmelt
12/14/77	Dormant	Large	0002	2650	7	Snowmelt
3/13/78	Dormant	Large	1609	4350	8	Snowmelt
5/13/78	Growing	Small	1724	2330	7	Rainfall
9/14/78	Growing	Small	1810	2130	6	Rainfall
10/12/78	Growing	Large	1809	1933	7	Rainfall
12/3/78	Dormant	Small	1134	2810	8	Rainfall
12/8/78	Dormant	Small	1136	2921	6	Rainfall
2/23/79	Dormant	Large	0820	4020	6	Snowmelt
2/25/79	Dormant	Large	1203	2700	6	Snowmelt
7/22/79	Growing	Small	1942	2032	15	Rainfall
7/25/79	Growing	Small	1252	1332	9	Rainfall
8/1/79	Growing	Large	1908	2235	15	Rainfall
8/18/79	Growing	Large	0318	1415	15	Rainfall
9/14/79	Growing	Large	0147	1020	16	Rainfall
9/27/79	Growing	Small	2044	3600	6	Rainfall
2/21/80	Dormant	Small	2302	2515	15	Rainfall

*Runoff events were selected for study if there were at least five discrete samples within an event and if the runoff was initiated by rainfall.

#Dormant season is November through April. Growing season is May through October.

**Large runoff events were those with the equivalent of ≥ 0.75 cm of water over the experimental watershed. Small events have < 0.75 cm of water.

##All selected runoff events were initiated by rainfall, but when there was snow cover on the watershed, the temperature was near freezing and the total runoff appeared larger than would be expected by rainfall alone, then that event contained rainfall and snowmelt in the runoff and was listed as snowmelt.

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TABLE C-3. DATA ON RUNOFF EVENTS FROM WATERSHED 129 SELECTED FOR PERIODIC ANALYSIS*

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Date	Season#	Event size**	Runoff event time		Number of samples	Type of runoff##
			Start	Stop		
4/28/77	Dormant	Small	1109	2000	8	Rainfall
7/4/77	Growing	Large	0617	1200	6	Rainfall
7/16/77	Growing	Large	1738	2200	5	Rainfall
7/21/77	Growing	Small	1608	2830	6	Rainfall
9/19/77	Growing	Large	0611	2344	9	Rainfall
9/26/77	Growing	Small	0702	0835	6	Rainfall
10/1/77	Growing	Large	0616	1010	6	Rainfall
11/7/77	Dormant	Small	1723	2045	15	Rainfall
11/30/77	Dormant	Small	0430	2600	10	Snowmelt
12/5/77	Dormant	Large	0547	1233	7	Snowmelt
12/13/77	Dormant	Large	1510	3642	7	Snowmelt
1/7/78	Dormant	Large	1311	2650	6	Snowmelt
3/13/78	Dormant	Large	1250	4015	7	Snowmelt
3/26/78	Dormant	Small	0055	2425	6	Rainfall
4/18/78	Dormant	Small	1122	2655	6	Rainfall
4/20/78	Dormant	Small	0555	2800	14	Rainfall
5/8/78	Growing	Small	1530	2400	6	Rainfall
8/5/78	Growing	Large	2242	2658	7	Rainfall
8/30/78	Growing	Small	1146	2540	15	Rainfall
9/14/78	Growing	Large	1913	2152	7	Rainfall
11/17/78	Dormant	Small	0400	1855	16	Rainfall
12/3/78	Dormant	Large	0730	3225	5	Rainfall
12/8/78	Dormant	Large	0131	2838	8	Rainfall
12/31/78	Dormant	Small	1250	1830	6	Rainfall
2/25/79	Dormant	Large	1124	2700	5	Snowmelt
4/2/79	Dormant	Small	0713	1009	5	Rainfall
4/4/79	Dormant	Small	0958	1536	16	Rainfall
4/9/79	Dormant	Large	0212	0936	9	Rainfall
4/12/79	Dormant	Small	0320	0625	5	Rainfall
4/13/79	Dormant	Small	2106	2359	6	Rainfall
5/12/79	Growing	Small	1408	1826	12	Rainfall
5/29/79	Growing	Small	2042	2230	7	Rainfall
6/21/79	Growing	Small	0406	0616	12	Rainfall
7/22/79	Growing	Large	1931	2054	15	Rainfall
7/25/79	Growing	Small	1237	1359	15	Rainfall
8/1/79	Growing	Large	1902	2127	15	Rainfall
8/11/79	Growing	Small	0304	0904	15	Rainfall
8/18/79	Growing	Large	0028	0745	15	Rainfall
8/23/79	Growing	Small	1941	2227	8	Rainfall
8/24/79	Growing	Small	1251	1554	9	Rainfall
9/13/79	Growing	Small	2405	3435	15	Rainfall
9/28/79	Growing	Small	0040	1000	13	Rainfall
11/26/79	Dormant	Small	0056	0525	7	Rainfall

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TABLE C-3. (continued)

Date	Season#	Event size**	Runoff event time Start	Runoff event time Stop	Number of samples	Type of runoff##
1/11/80	Dormant	Small	0424	1425	15	Rainfall
2/20/80	Dormant	Small	1126	4157	15	Snowmelt
2/21/80	Dormant	Small	1845	3011	10	Rainfall
3/5/80	Dormant	Small	0614	1935	15	Rainfall
3/7/80	Dormant	Large	1630	3735	16	Rainfall

*Runoff events were selected for study if there were at least five discrete samples within an event and if the runoff was initiated by rainfall.

#Dormant season is November through April. Growing season is May through October.

**Large runoff events were those with the equivalent of ≥ 0.75 cm of water over the experimental watershed. Small events have < 0.75 cm of water.

##All selected runoff events were initiated by rainfall, but when there was snow cover on the watershed, the temperature was near freezing and the total runoff appeared larger than would be expected by rainfall alone, then that event contained rainfall and snowmelt in the runoff and was listed as snowmelt.

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APPENDIX D

SCATTER PLOTS FOR NUTRIENT AND ORGANIC PARAMETERS

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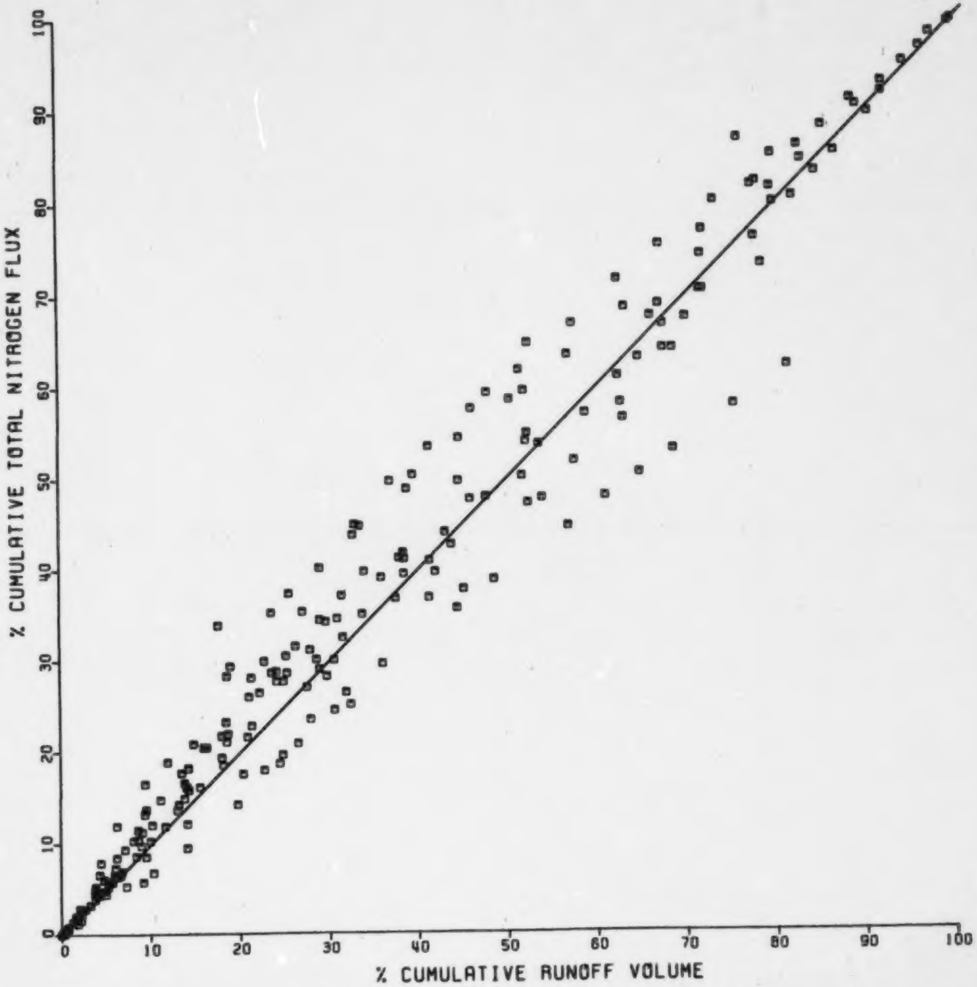

Figure D-1. Total nitrogen flux scatter plot for all discrete samples in all selected runoff events from WS 106 during study period.

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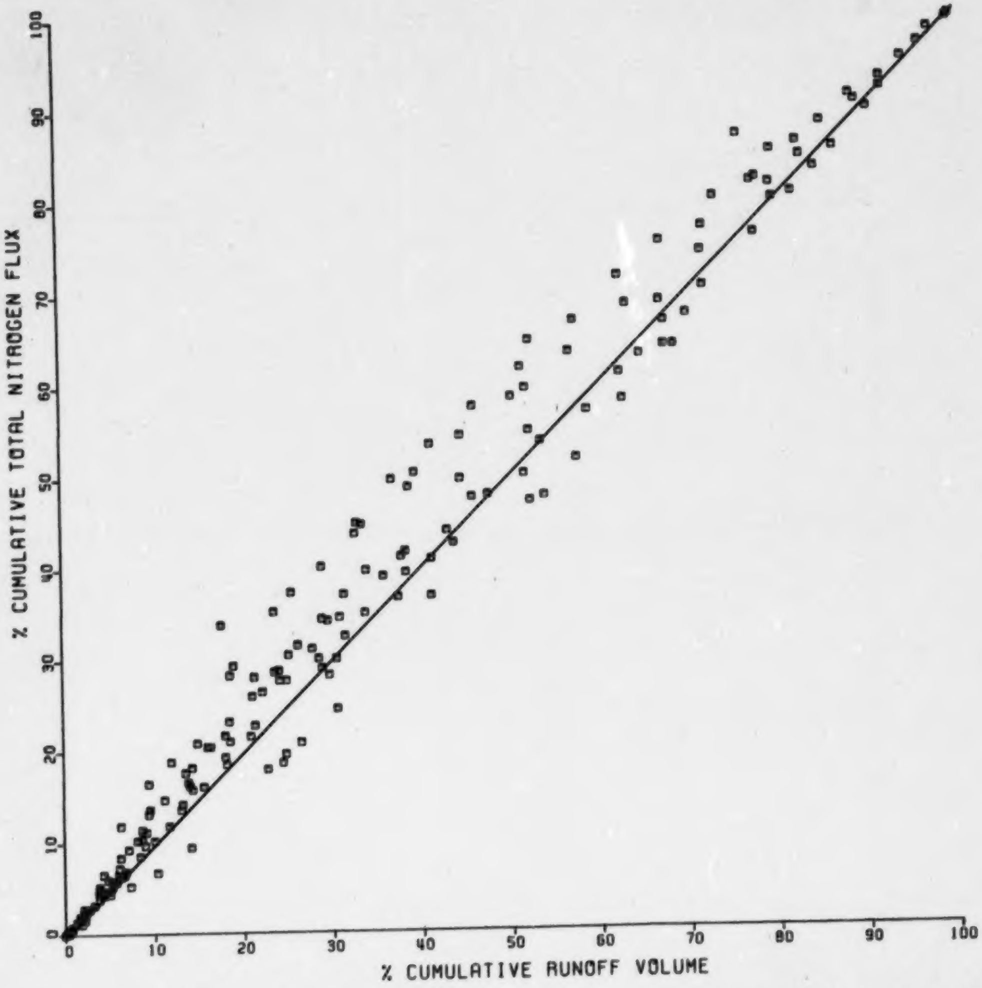

Figure D-2. Total nitrogen flux scatter plot for all discrete samples in dormant season selected runoff events from WS 106 during study period.

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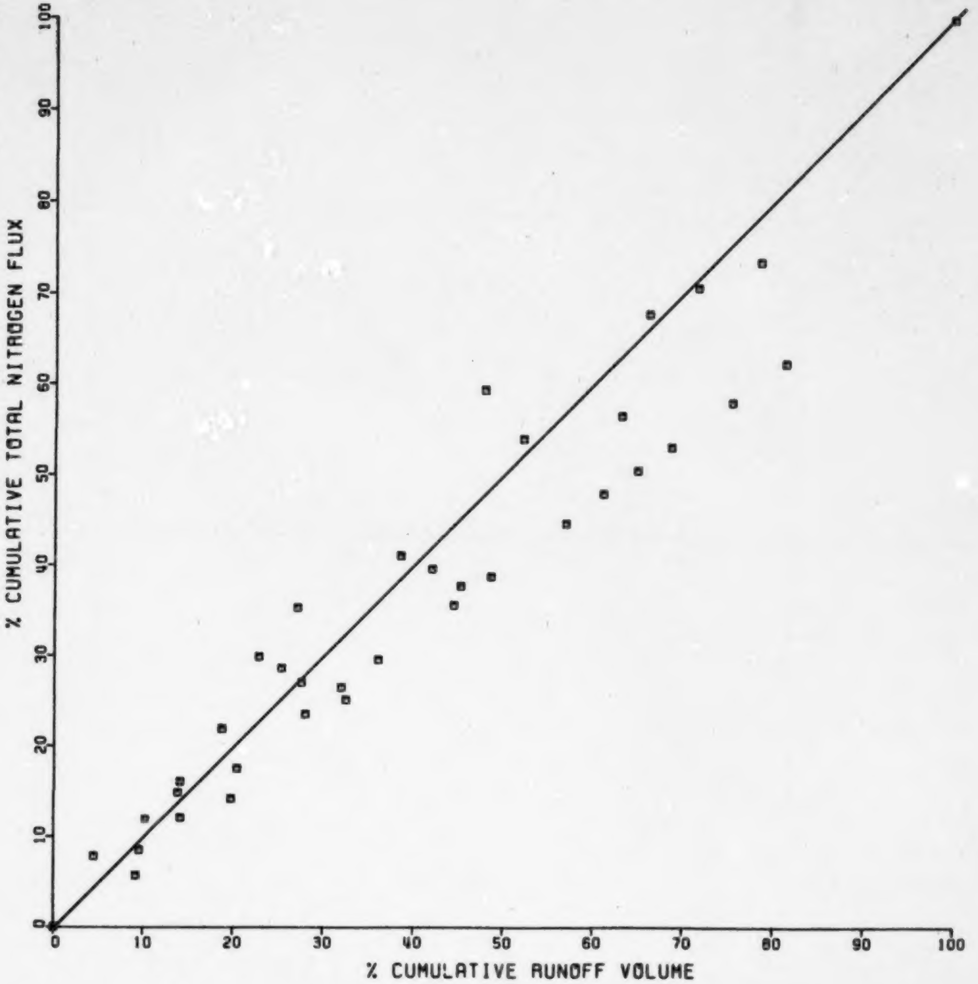

Figure D-3. Total nitrogen flux scatter plot for all discrete samples in growing season selected runoff events from WS 106 during study period.

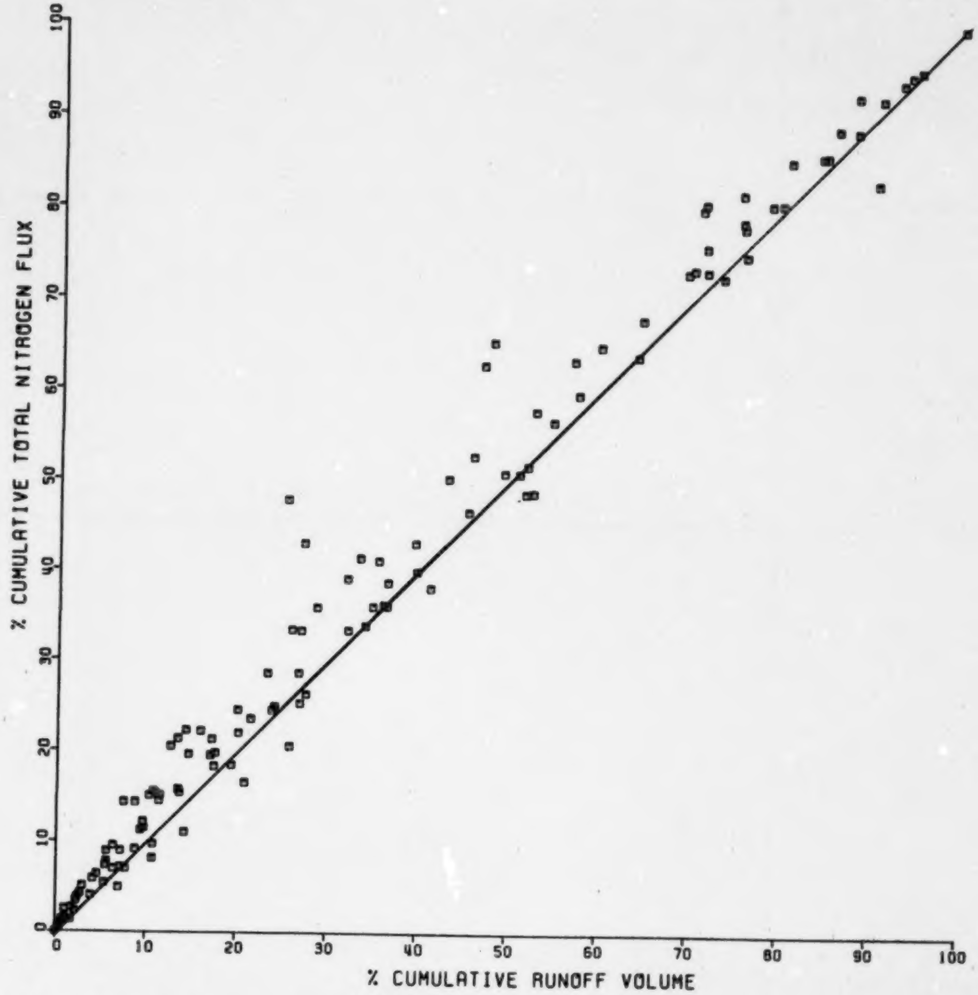

Figure D-4. Total nitrogen flux scatter plot for all discrete samples in all selected runoff events from WS 110 during study period.

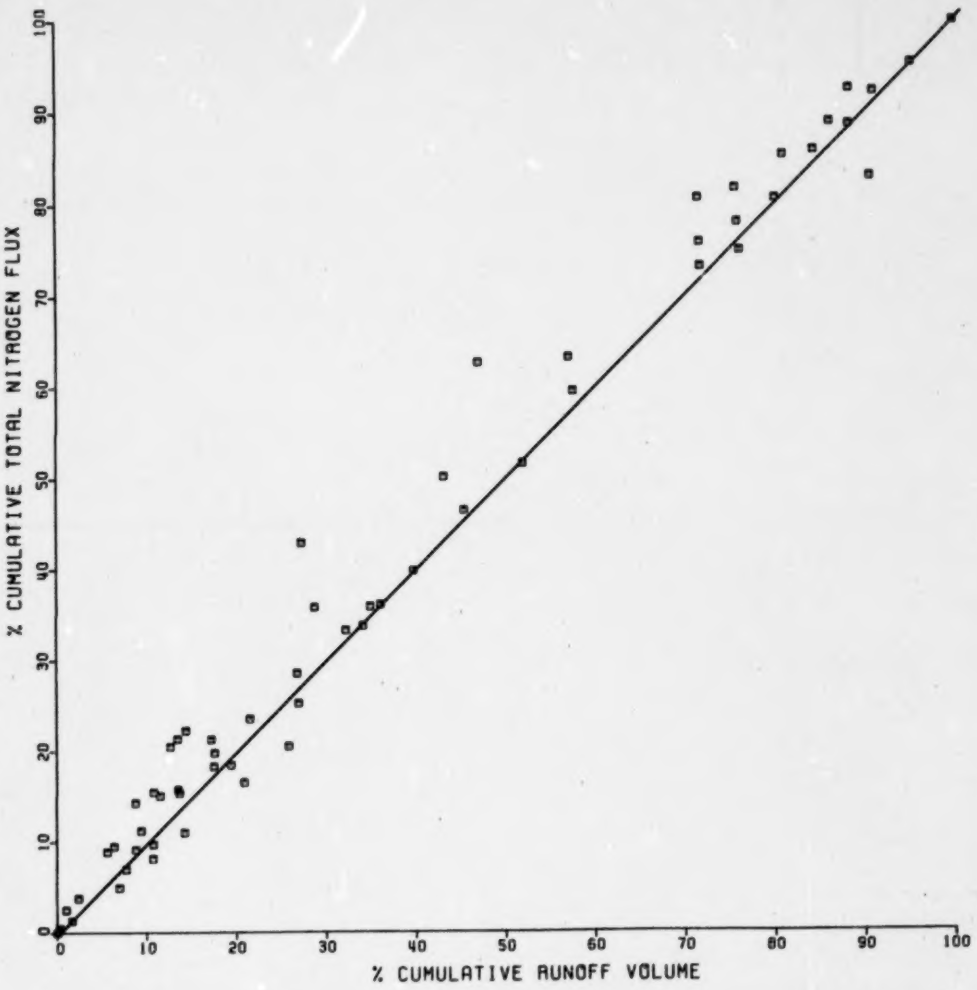

Figure D-5. Total nitrogen flux scatter plot for all discrete samples in dormant season selected runoff events from WS 110 during study period.

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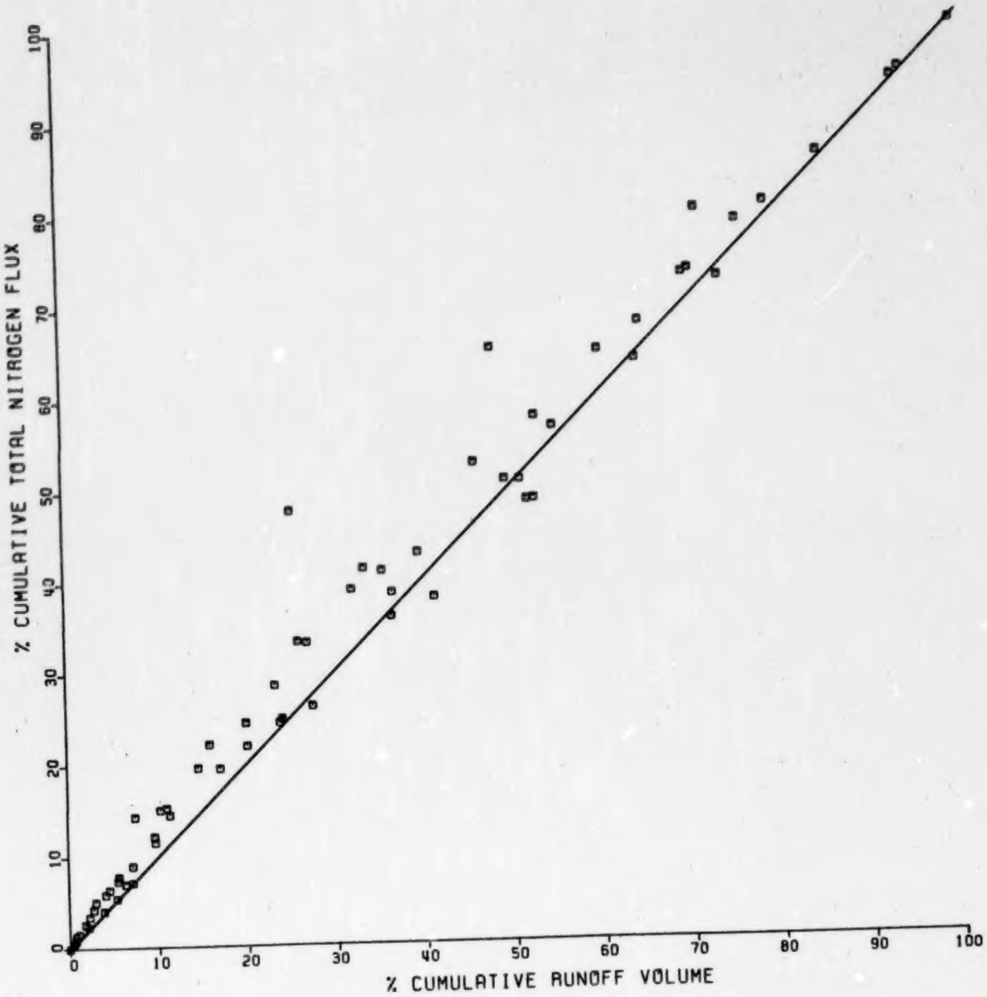

Figure D-6. Total nitrogen flux scatter plot for all discrete samples in growing season selected runoff events from WS 110 for study period.

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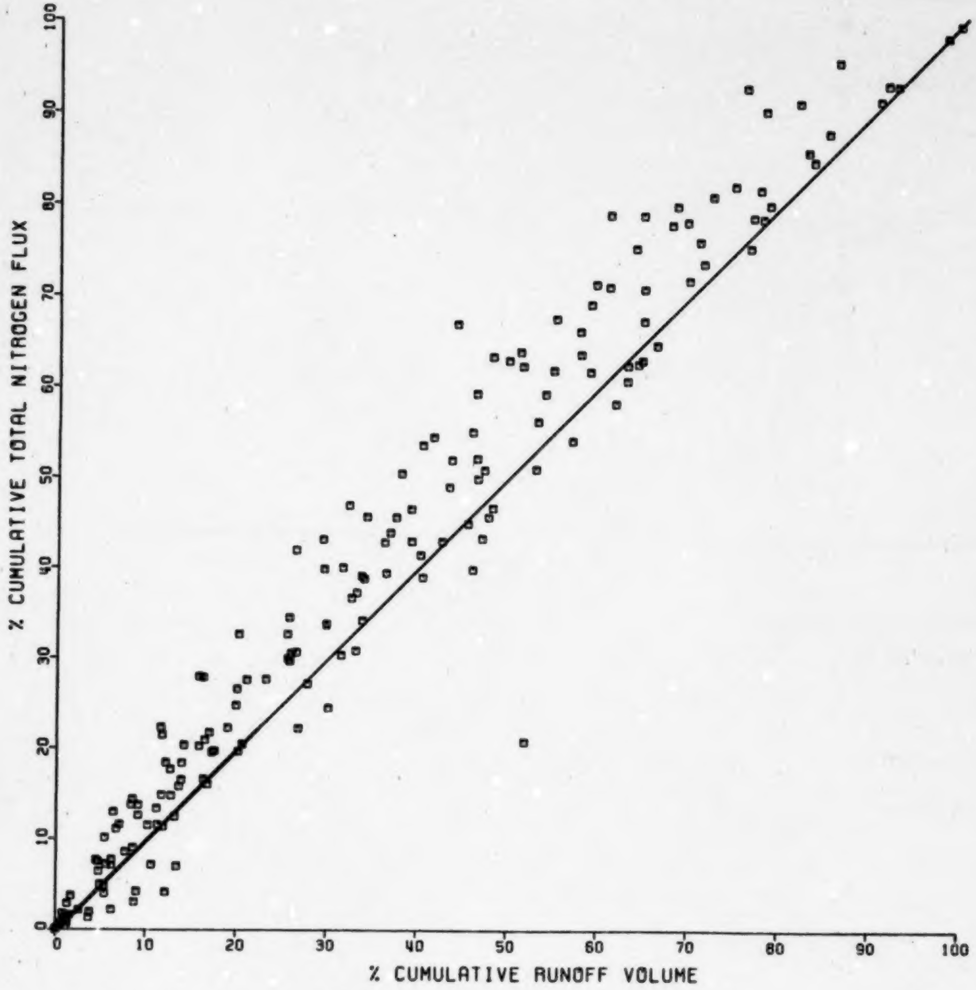

Figure D-7. Total nitrogen flux scatter plot for all discrete samples in dormant season selected runoff events from WS 129 during study period.

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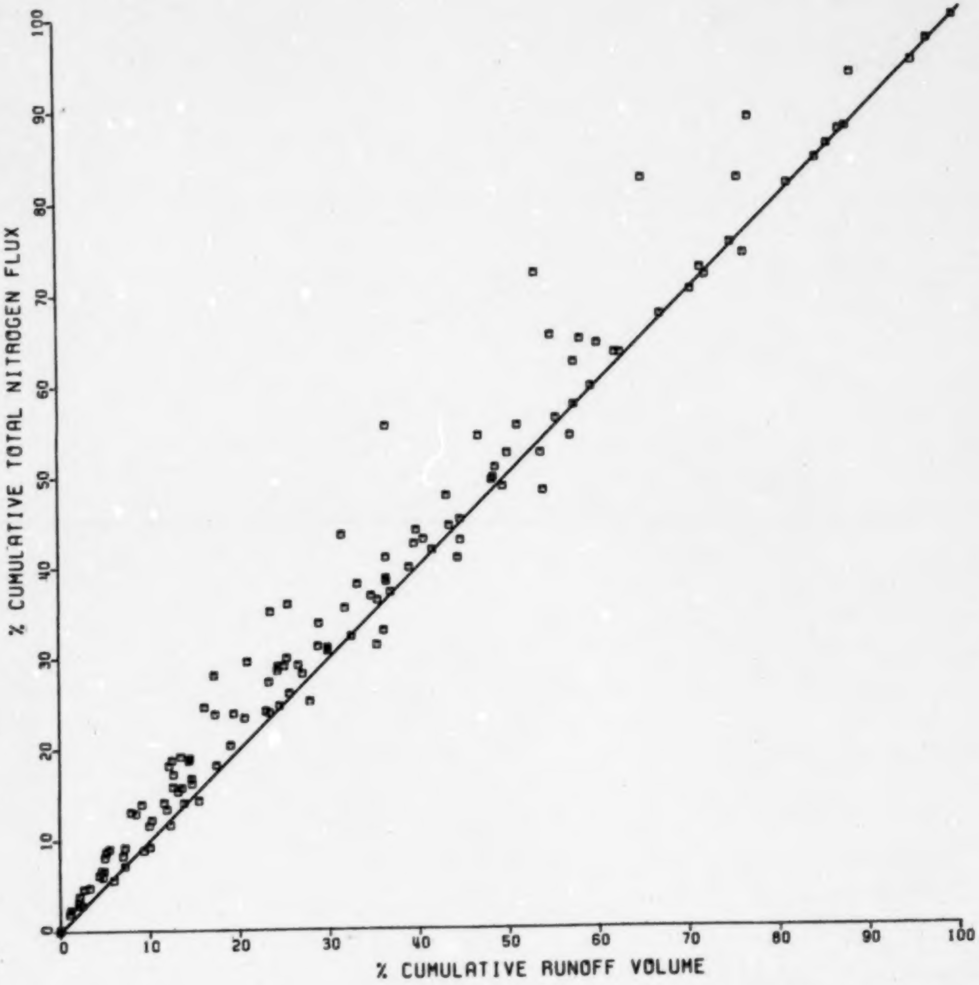

Figure D-8. Total nitrogen flux scatter plot for all discrete samples in growing season selected runoff events from WS 129 during study period.

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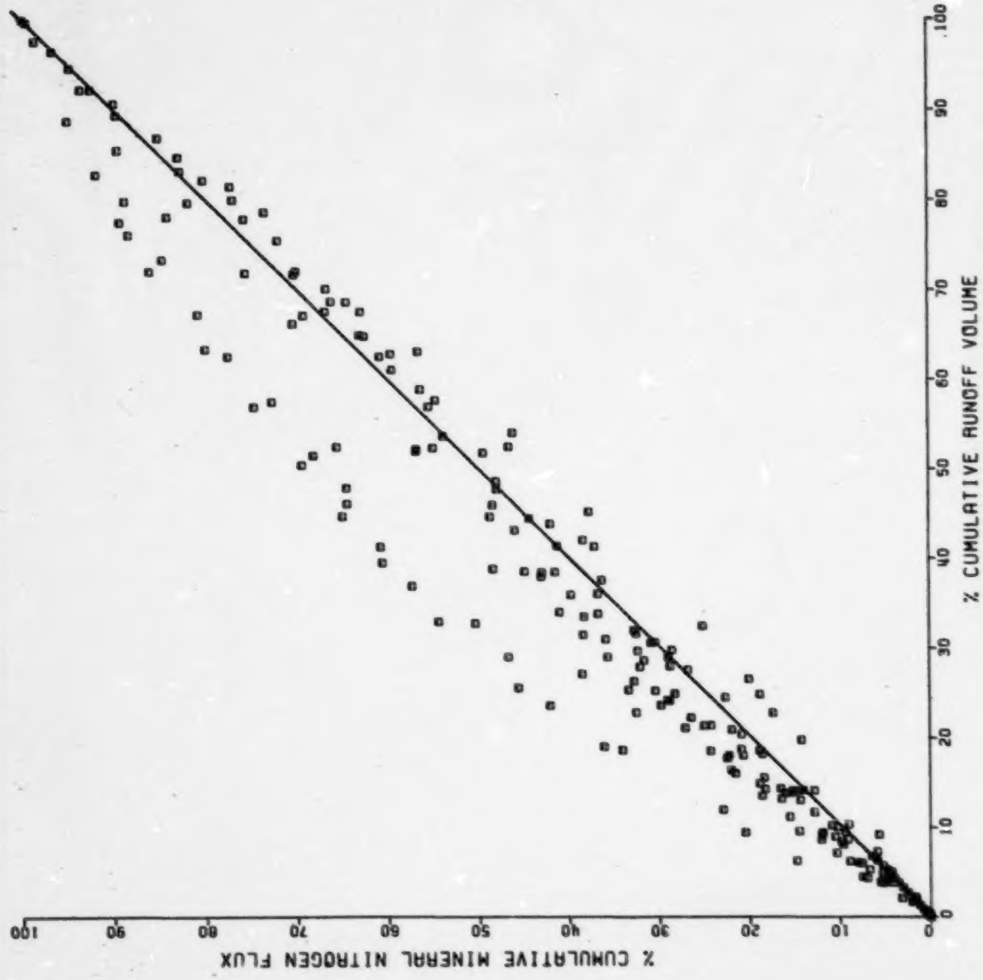

Figure D-9. Mineral nitrogen flux scatter plot for all discrete samples in all selected runoff events from WS 106 during study period.

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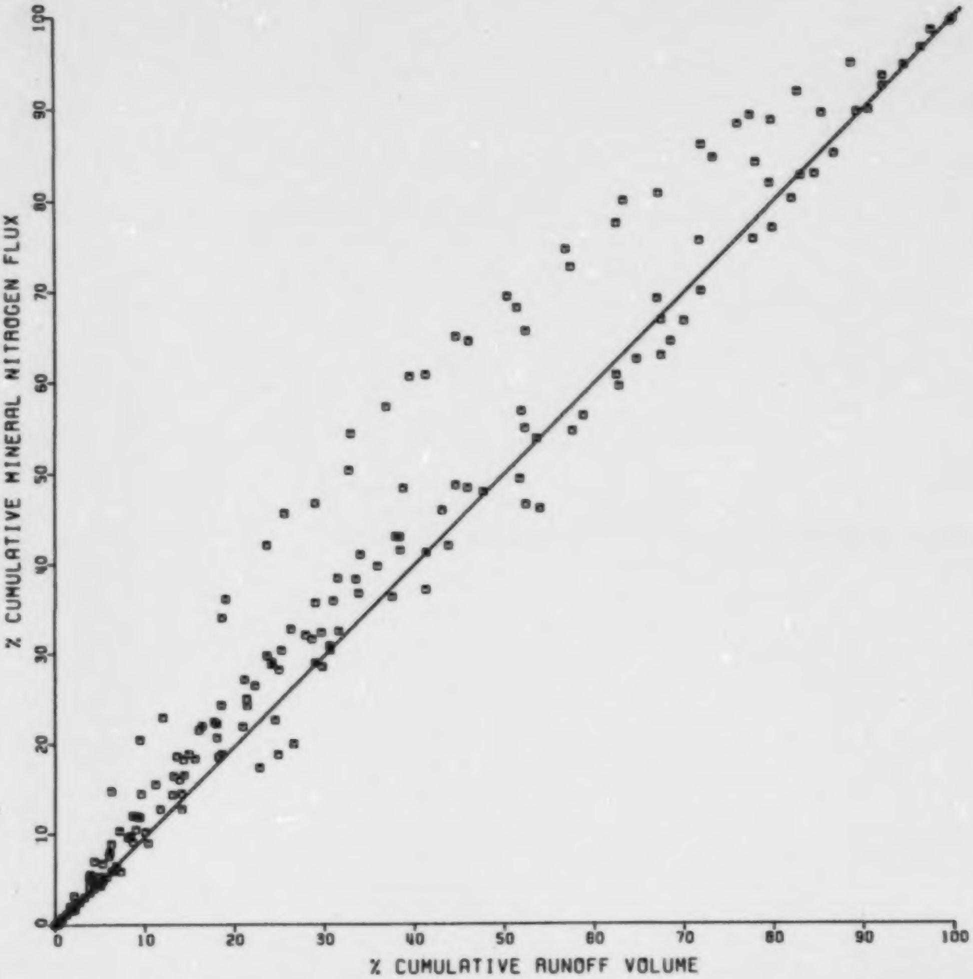

Figure D-10. Mineral nitrogen flux scatter plot for all discrete samples in dormant season selected runoff events from WS 106 during study period.

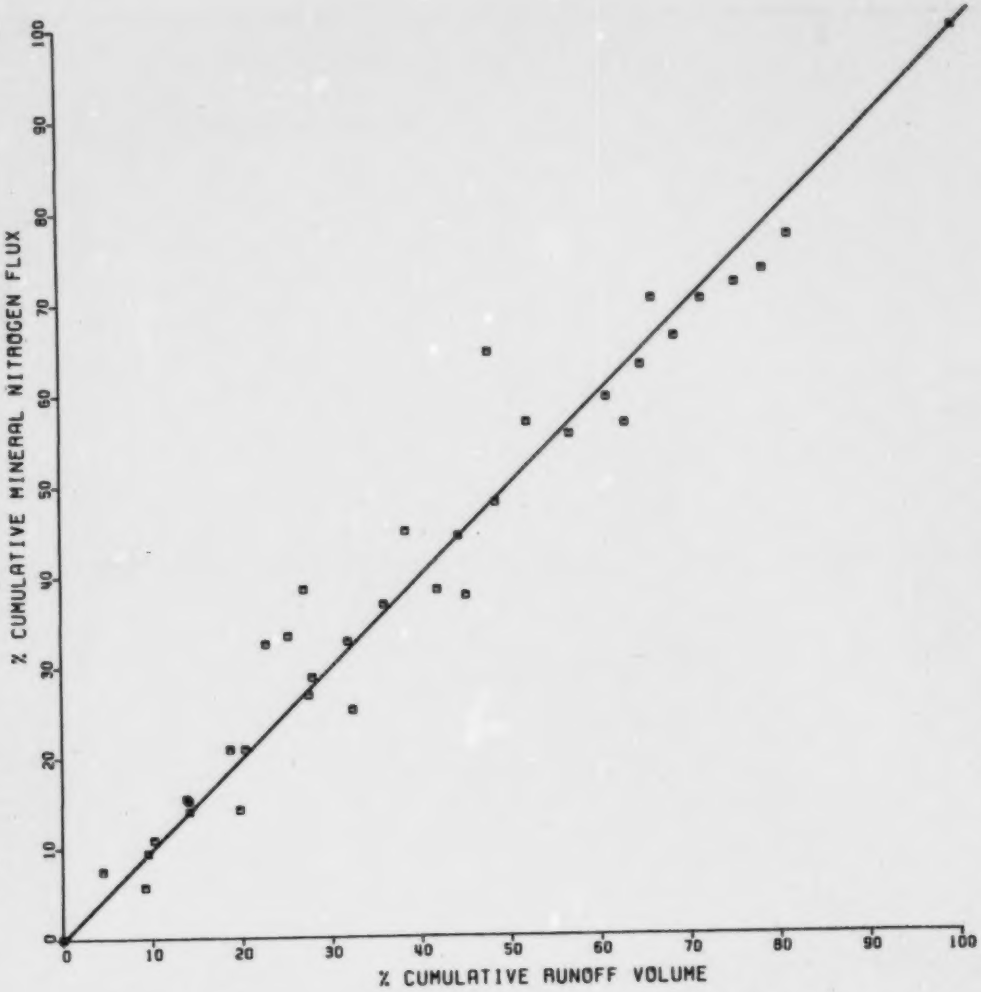

Figure D-11. Mineral nitrogen flux scatter plot for all discrete samples in growing season selected runoff events from WS 106 during study period.

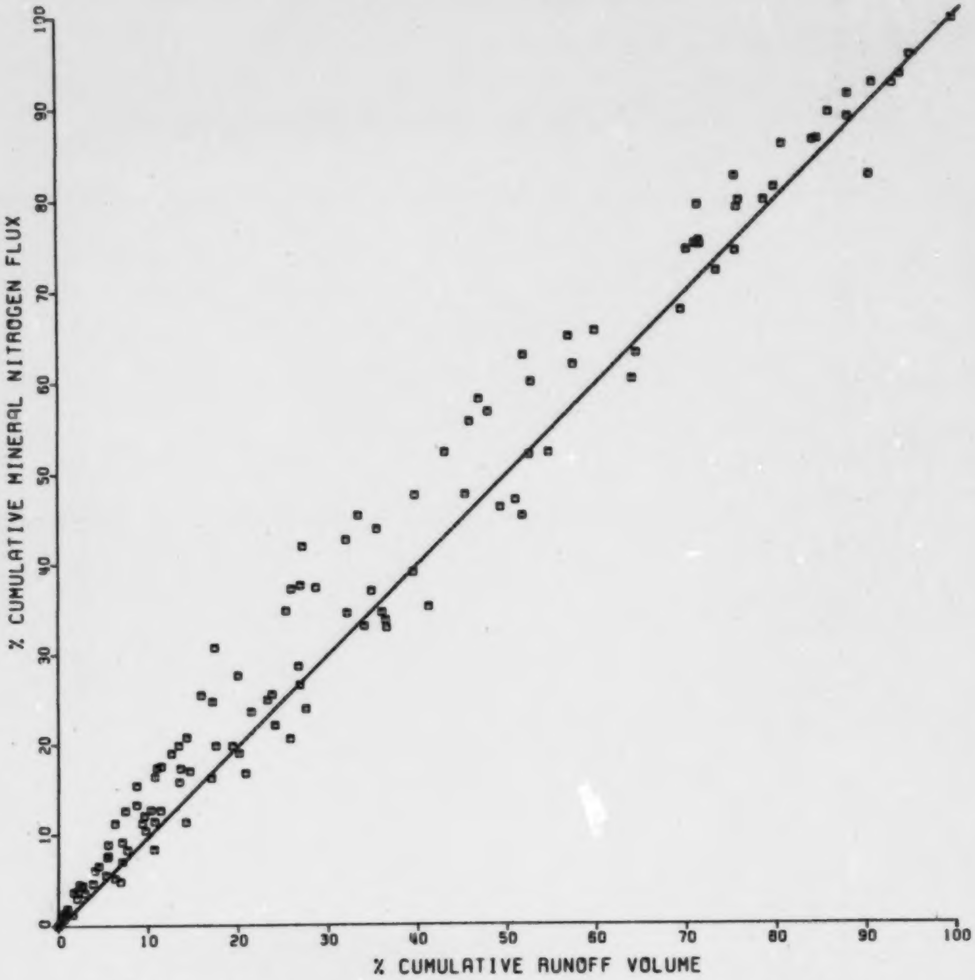

Figure D-12 . Mineral nitrogen flux scatter plot for all discrete samples in all selected runoff events from WS 110 during study period.

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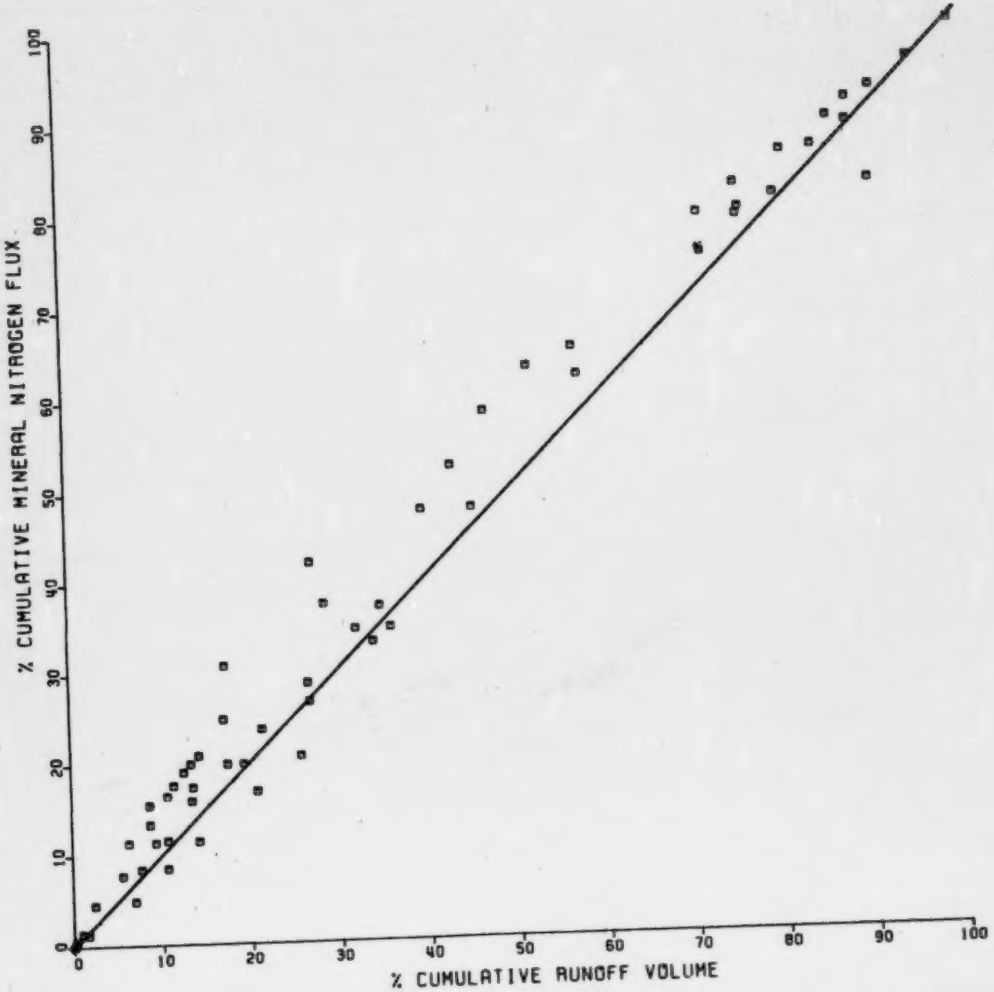

Figure D-13. Mineral nitrogen flux scatter plot for all discrete samples in dormant season selected runoff events from WS 110 during study period.

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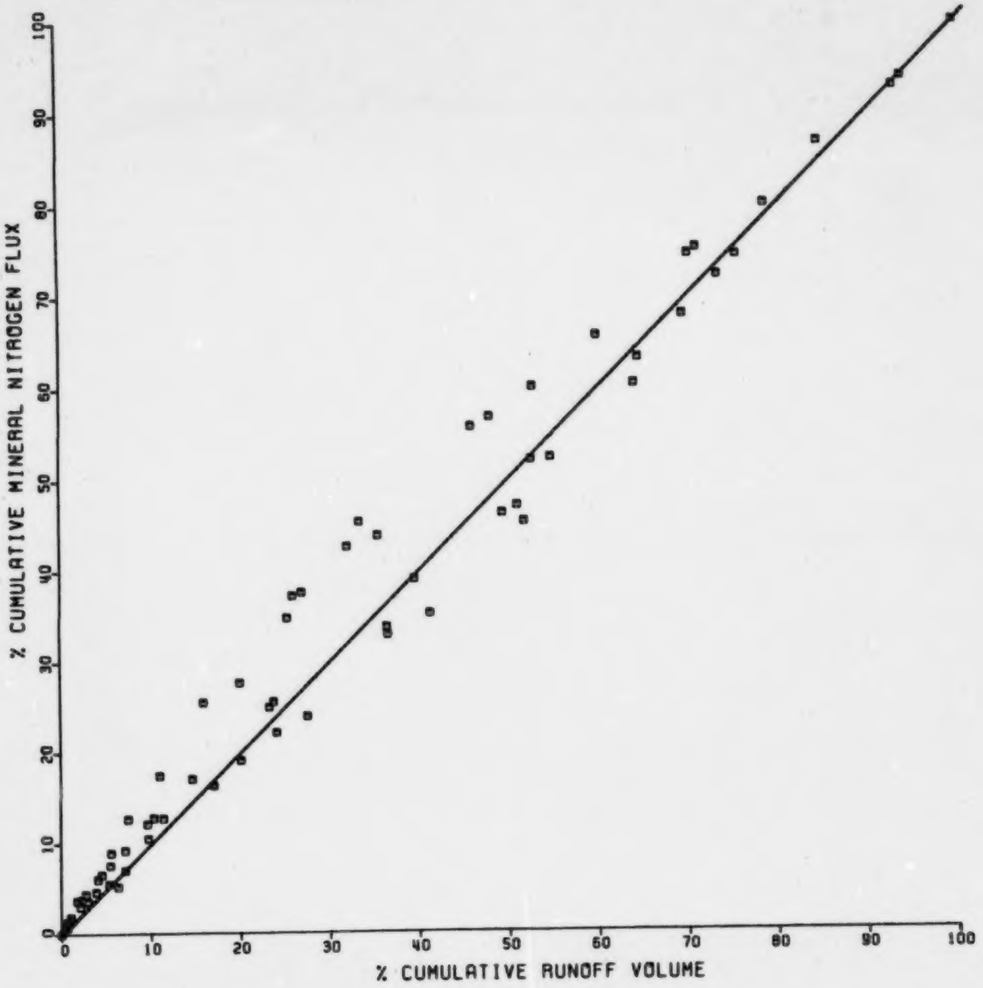

Figure D-14. Mineral nitrogen flux scatter plot for all discrete samples in growing season selected runoff events from WS 110 for study period.

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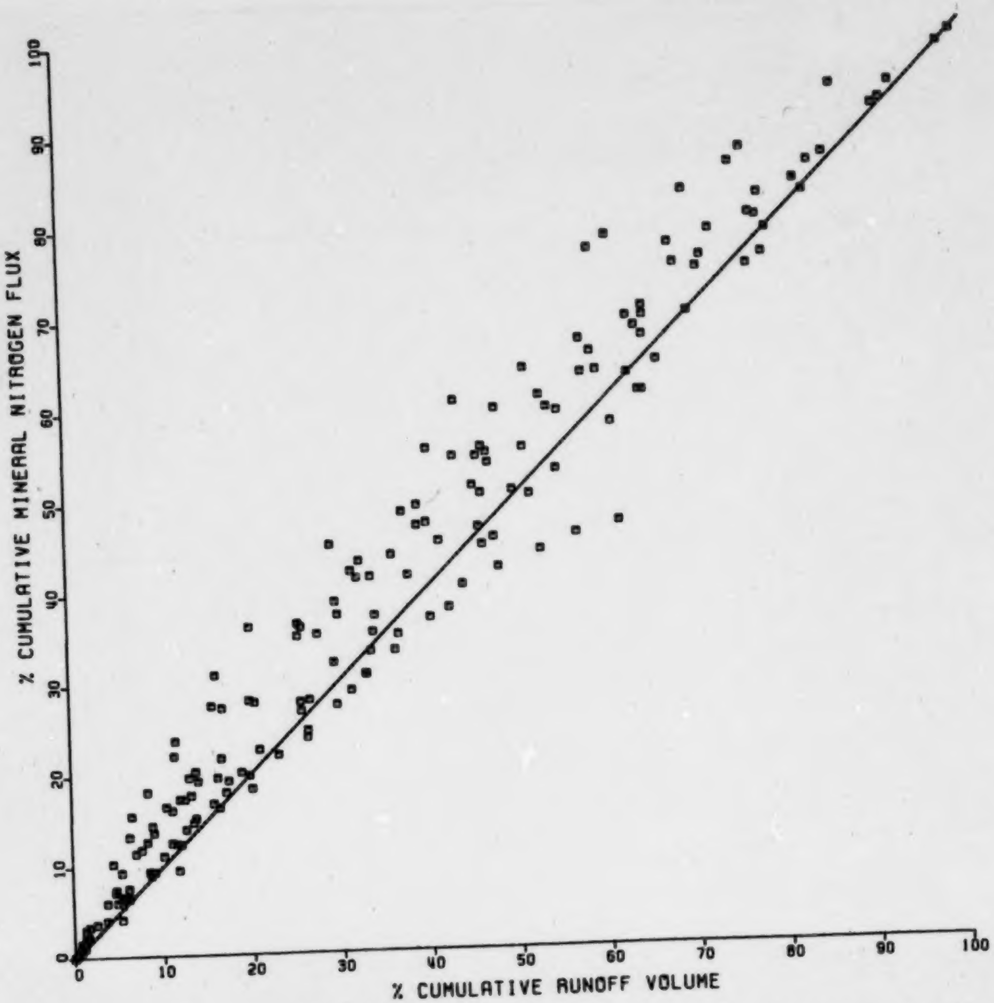

Figure D-15. Mineral nitrogen flux scatter plot for all discrete samples in dormant season selected runoff events from WS 129 during study period.

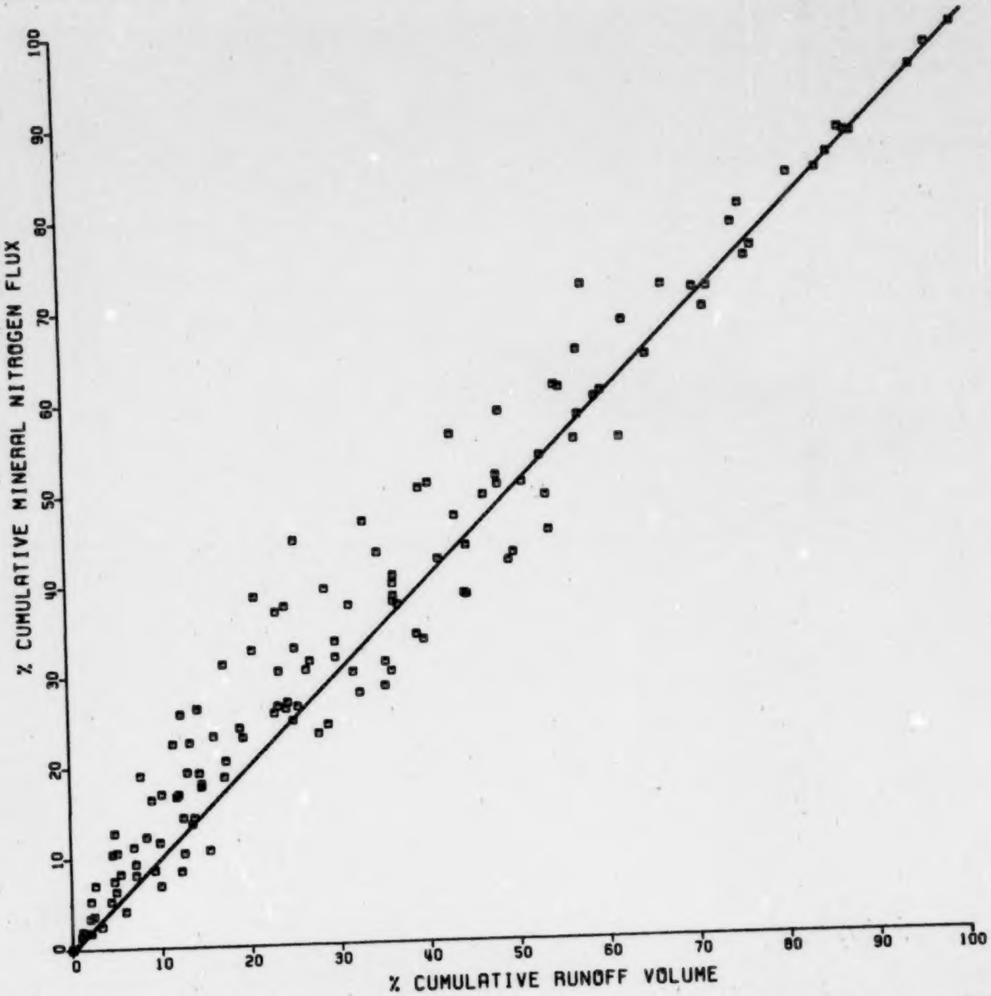

Figure D-16. Mineral nitrogen flux scatter plot for all discrete samples in growing season selected runoff events from WS 129 during study period.

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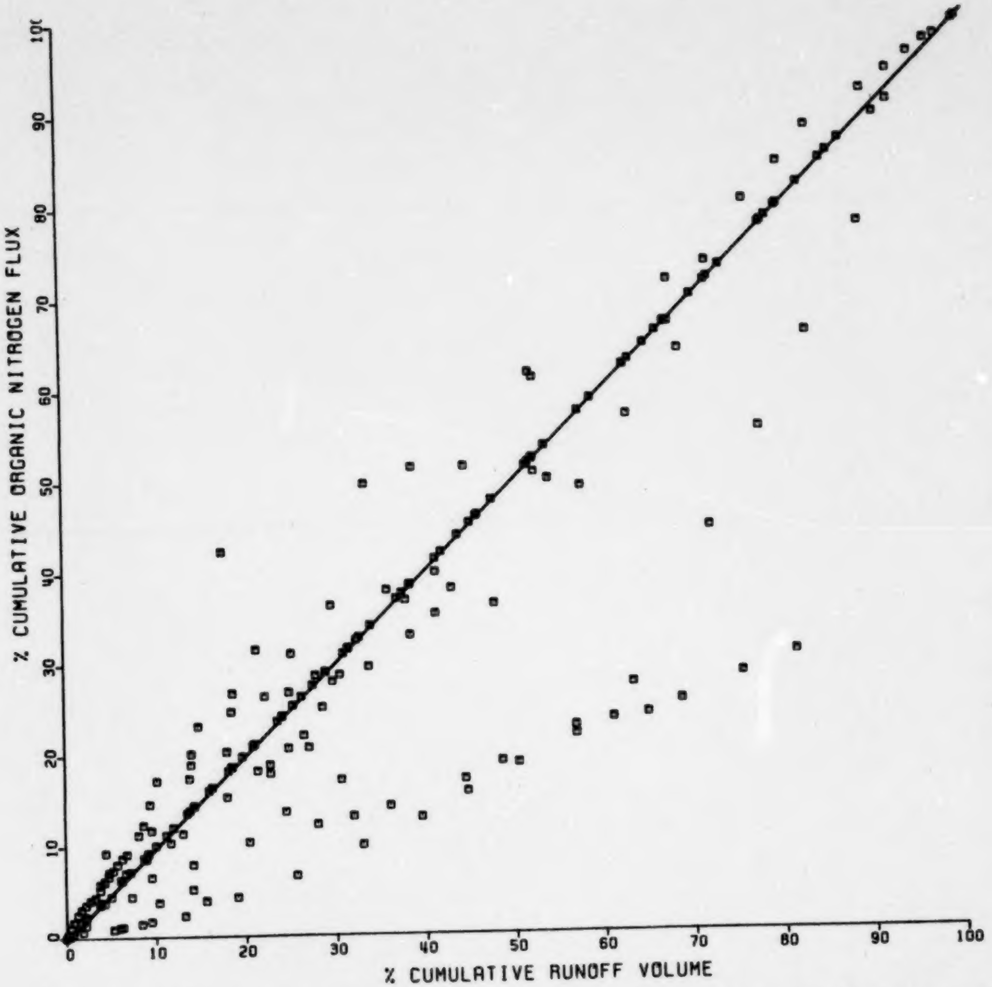

Figure D-17. Organic nitrogen flux scatter plot for all discrete samples in all selected runoff events from WS 106 during study period.

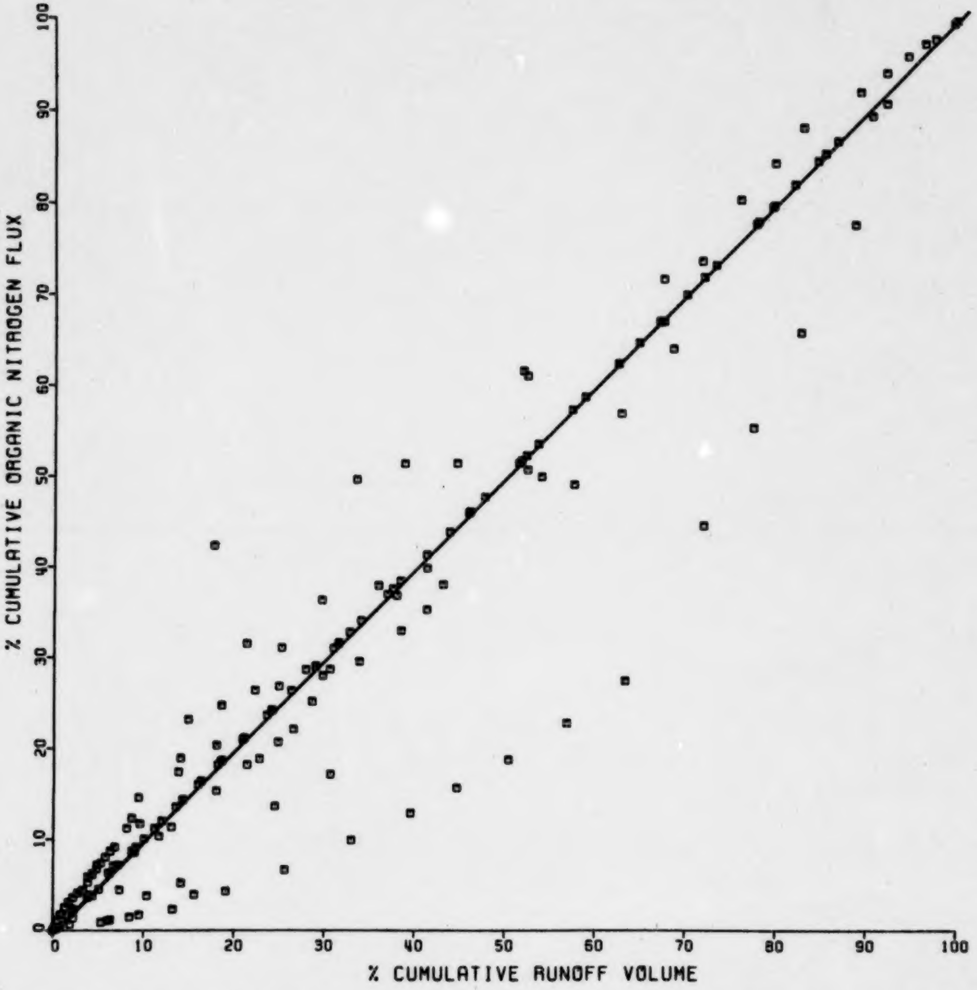

Figure D-18. Organic nitrogen flux scatter plot for all discrete samples in dormant season selected runoff events from WS 106 during study period.

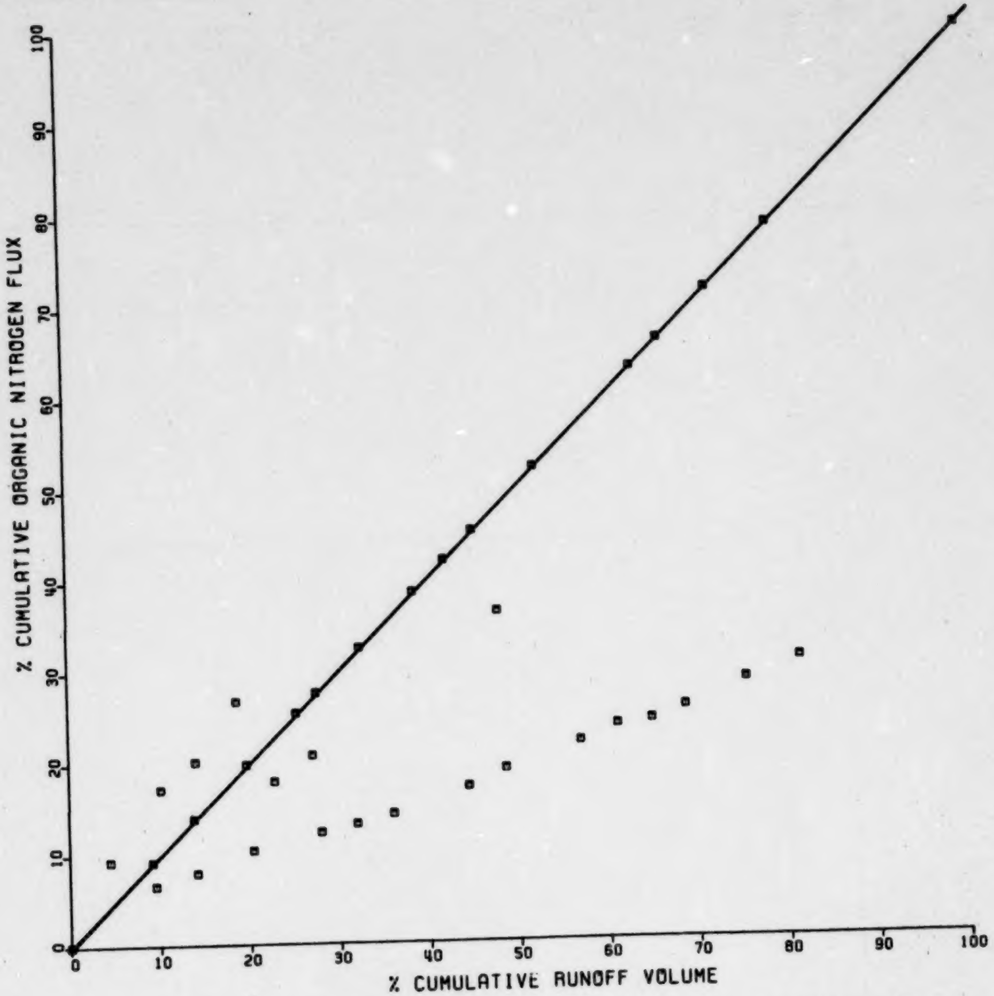

Figure D-19. Organic nitrogen flux scatter plot for all discrete samples in growing season selected runoff events from WS 106 during study period.

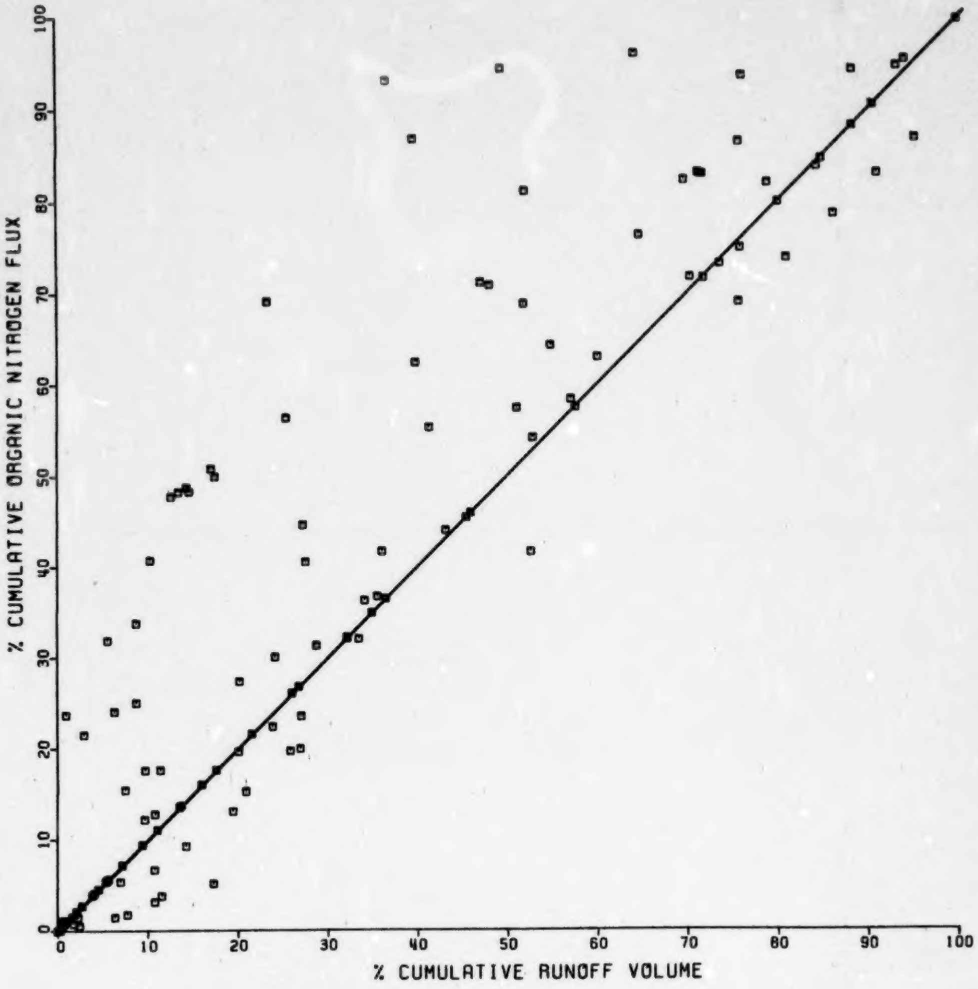

Figure D-20. Organic nitrogen flux scatter plot for all discrete samples in all selected runoff events from WS 110 during study period.

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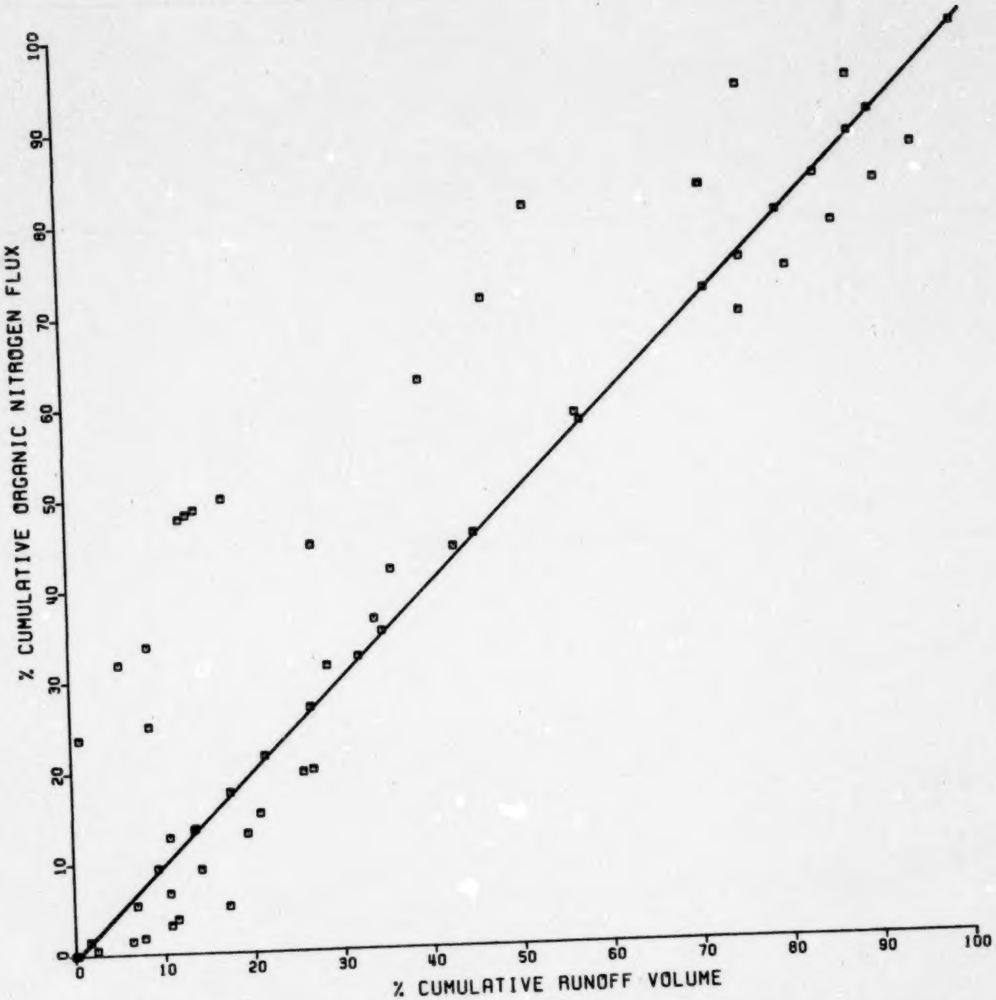

Figure D-21. Organic nitrogen flux scatter plot for all discrete samples in dormant season selected runoff events from WS 110 during study period.

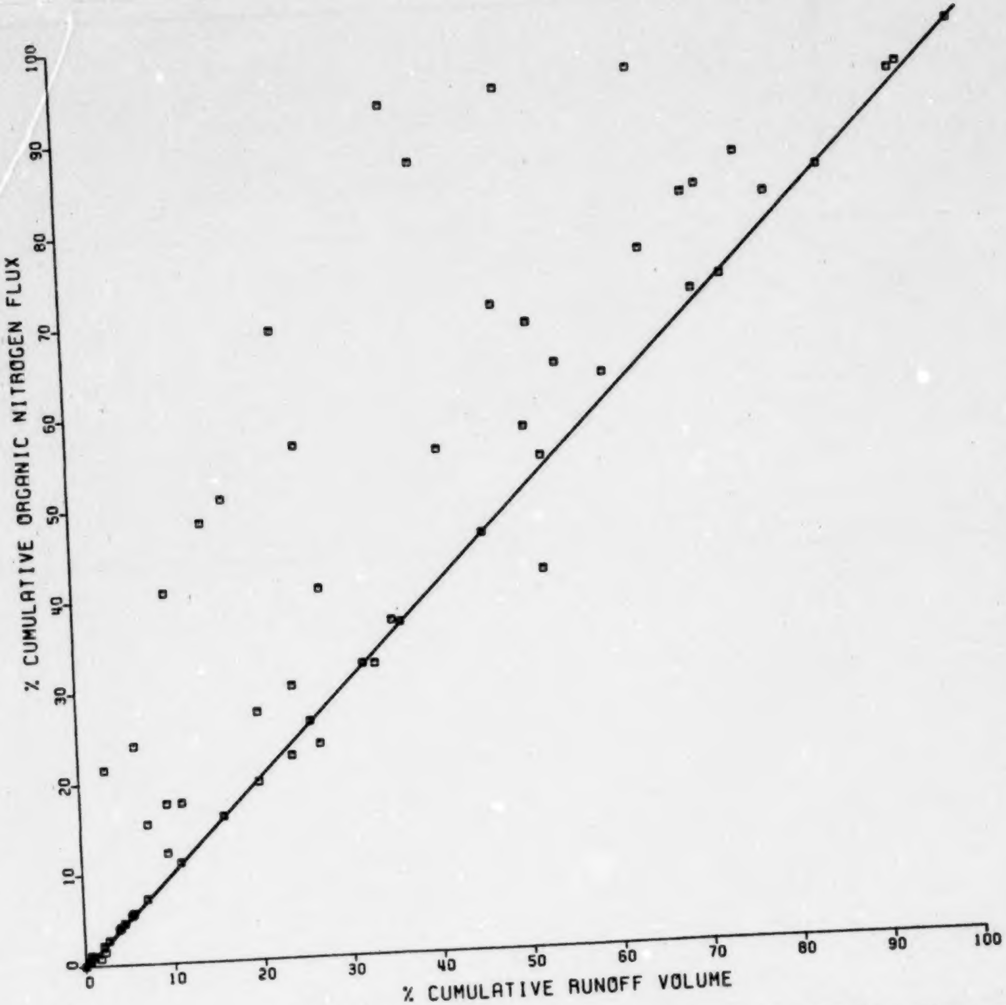

Figure D-22. Organic nitrogen flux scatter plot for all discrete samples in growing season selected runoff events from WS 110 for study period.

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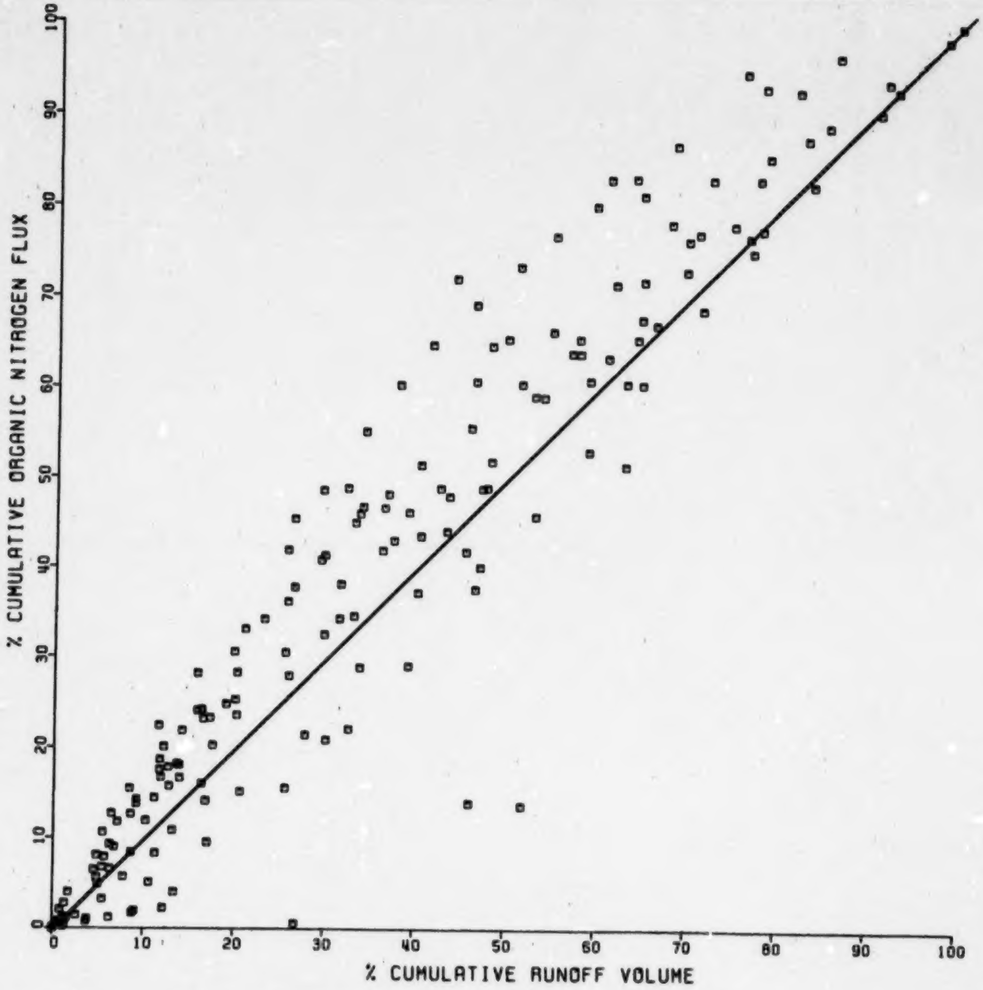

Figure D-23. Organic nitrogen flux scatter plot for all discrete samples in dormant season selected runoff events from WS 129 during study period.

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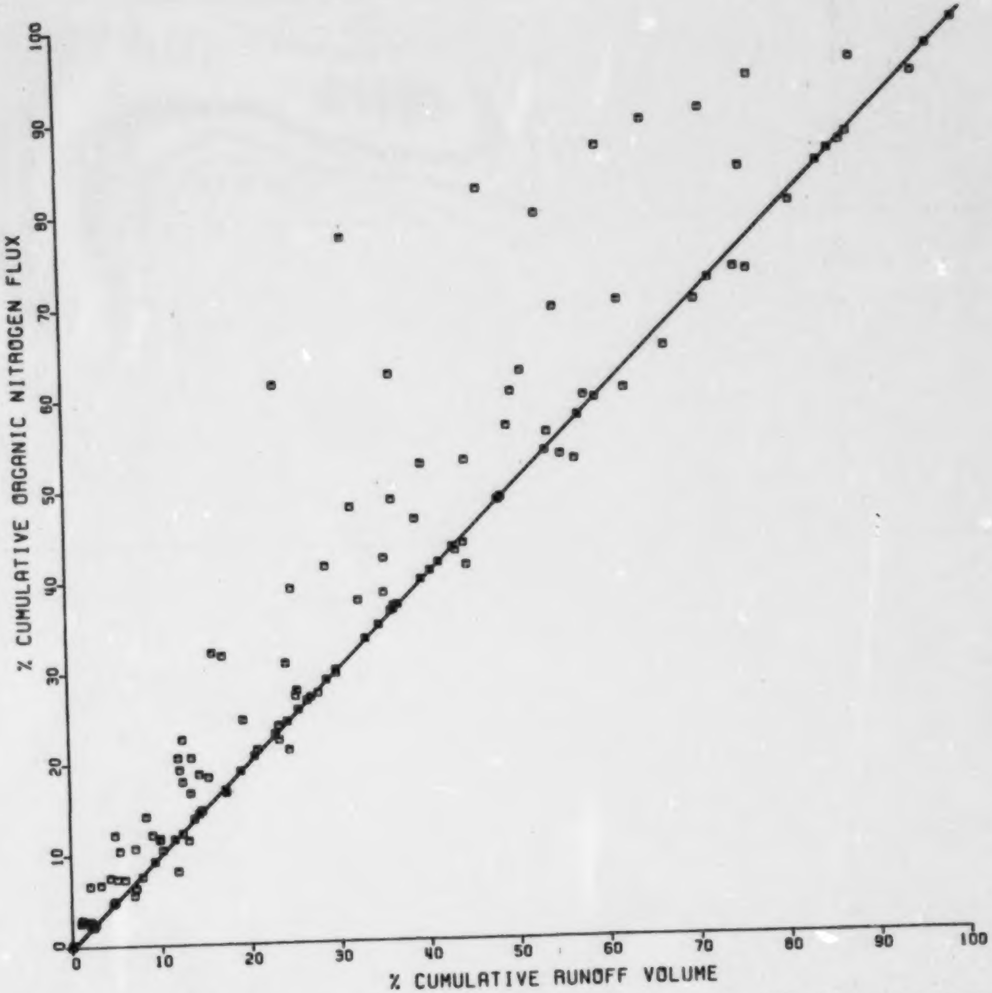

Figure D-24. Organic nitrogen flux scatter plot for all discrete samples in growing season selected runoff events from WS 129 during study period.

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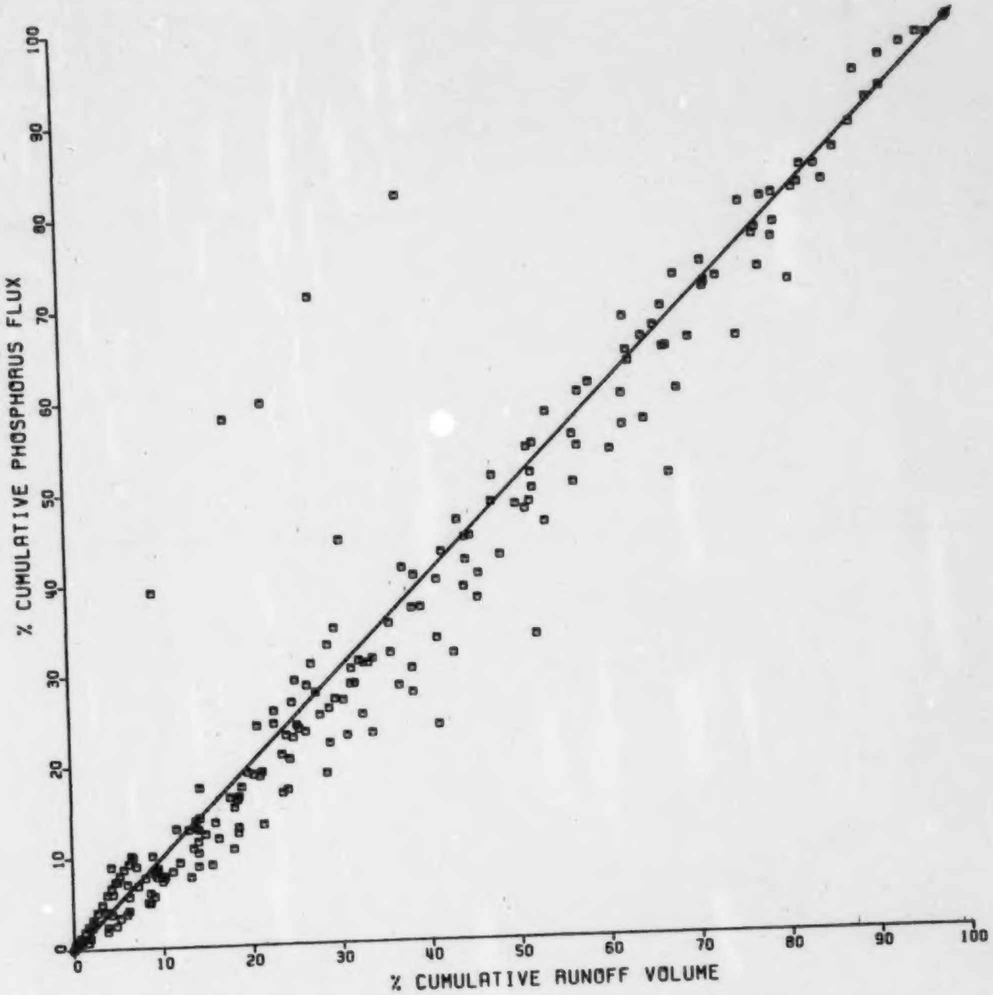

Figure D-25. Phosphorus flux scatter plot for all discrete samples in all selected runoff events from WS 106 during study period.

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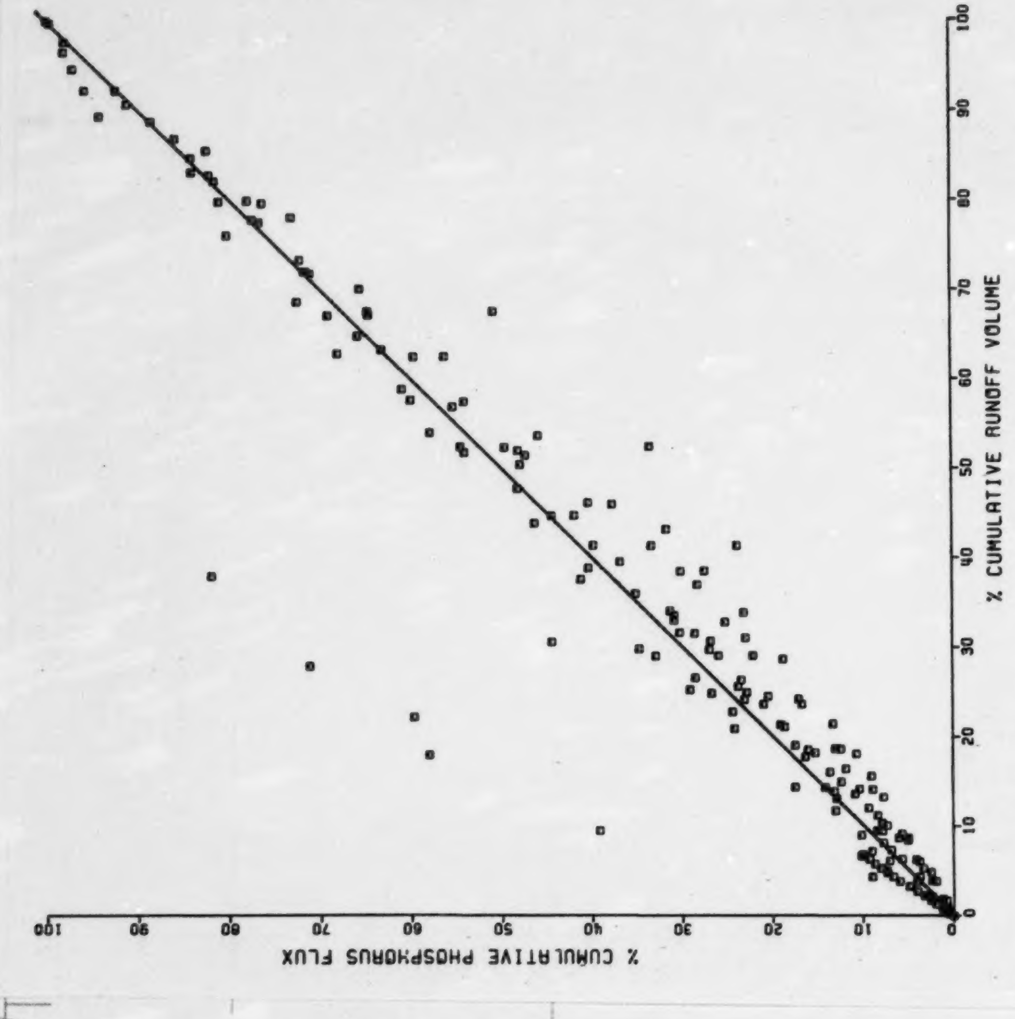

Figure D-26. Phosphorus flux scatter plot for all discrete samples in dormant season selected runoff events from WS 106 during study period.

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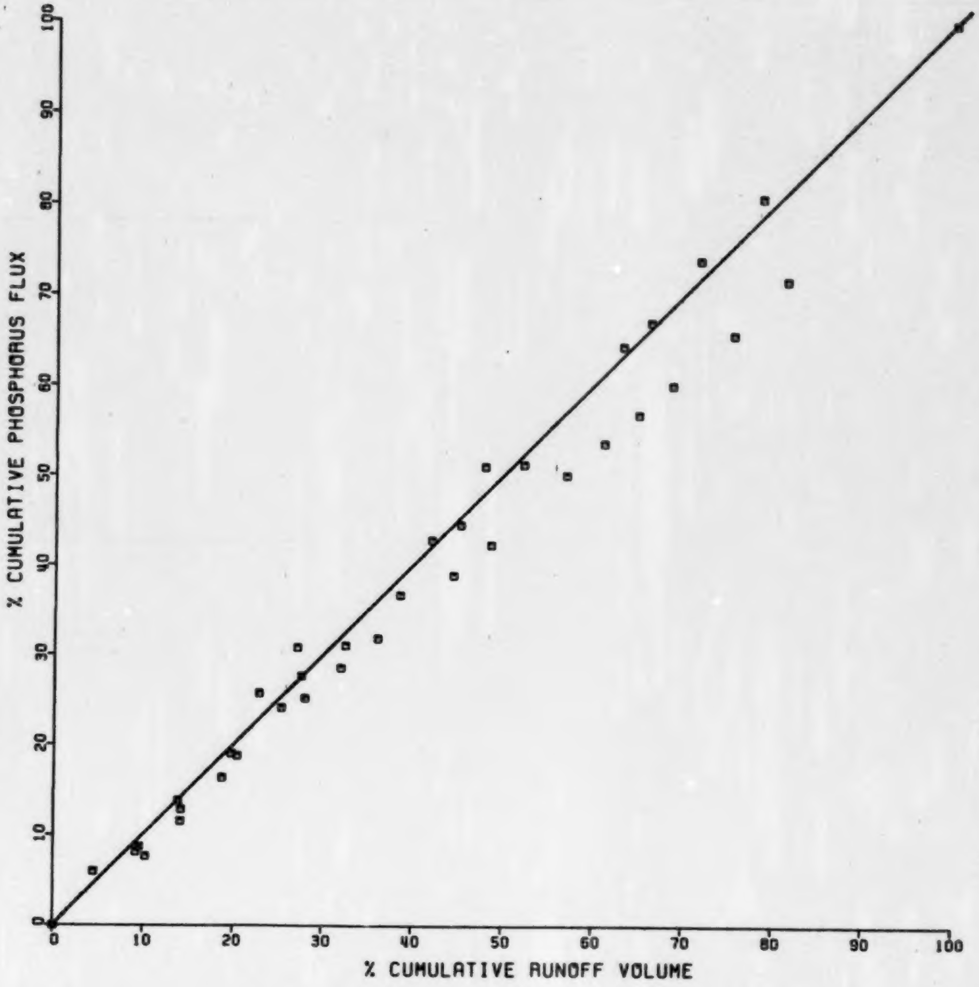

Figure D-27. Phosphorus flux scatter plot for all discrete samples in growing season selected runoff events from WS 106 during study period.

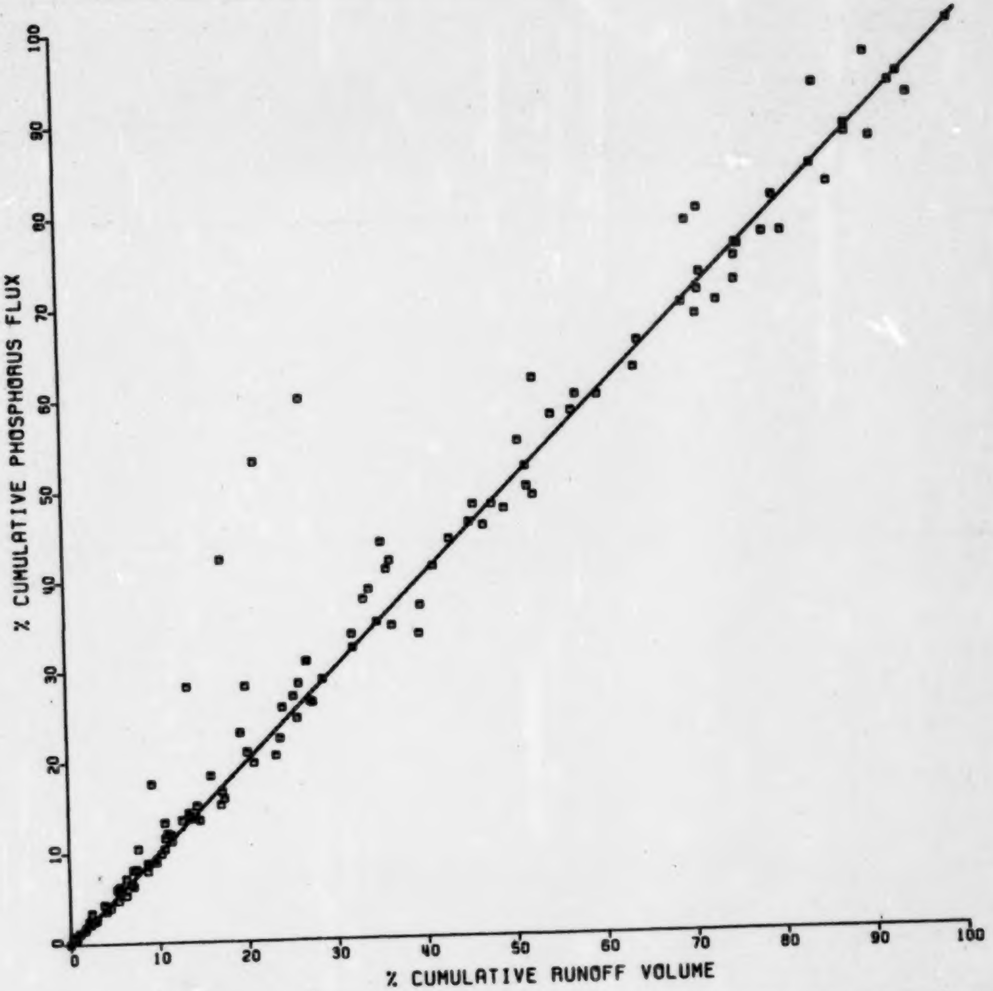

Figure D-28. Phosphorus flux scatter plot for all discrete samples in all selected runoff events from WS 110 during study period.

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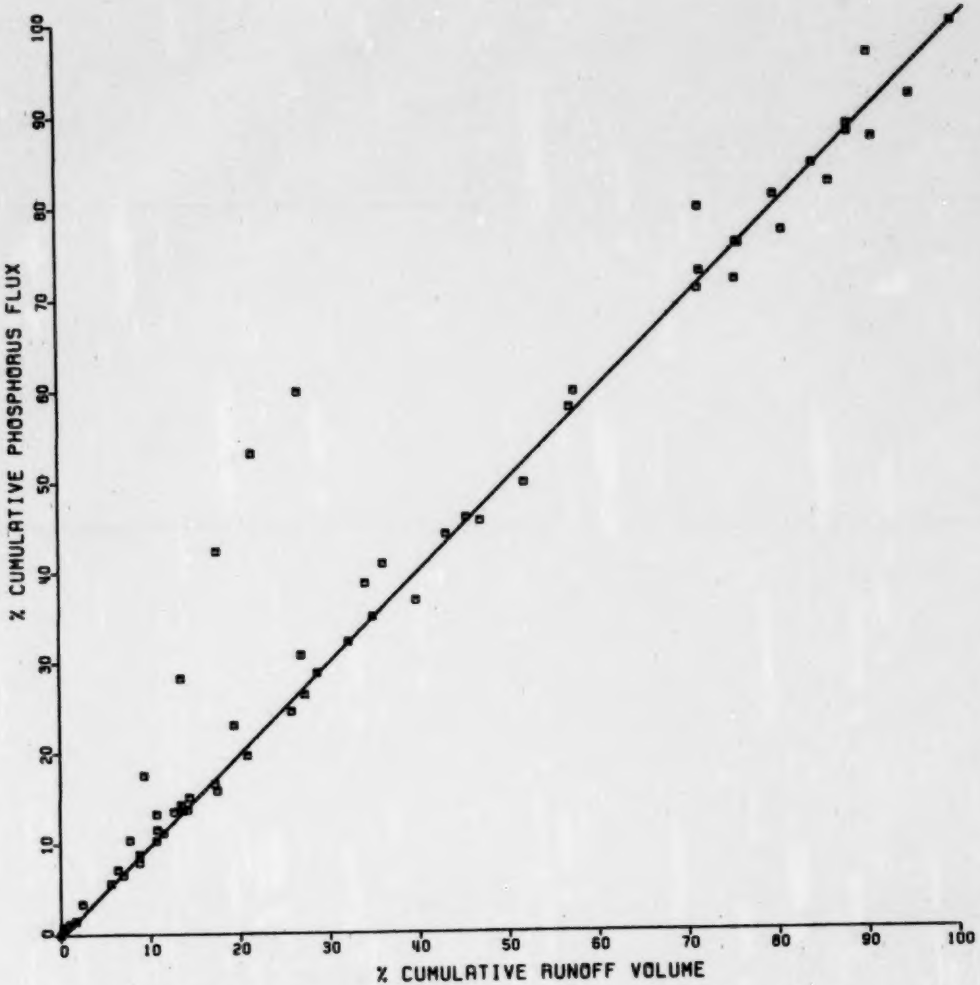

FigureD-29. Phosphorus flux scatter plot for all discrete samples in dormant season selected runoff events from WS 110 during study period.

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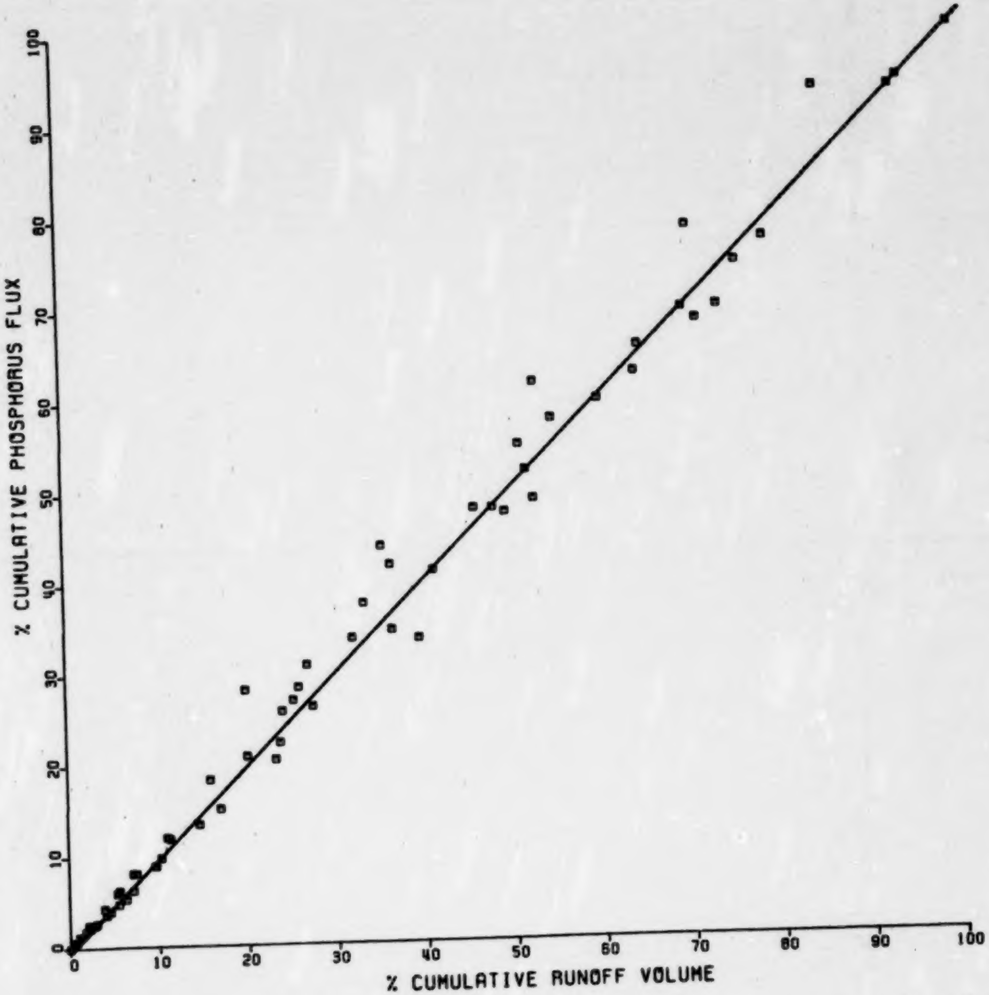

Figure D-30. Phosphorus flux scatter plot for all discrete samples in growing season selected runoff events from WS 110 for study period.

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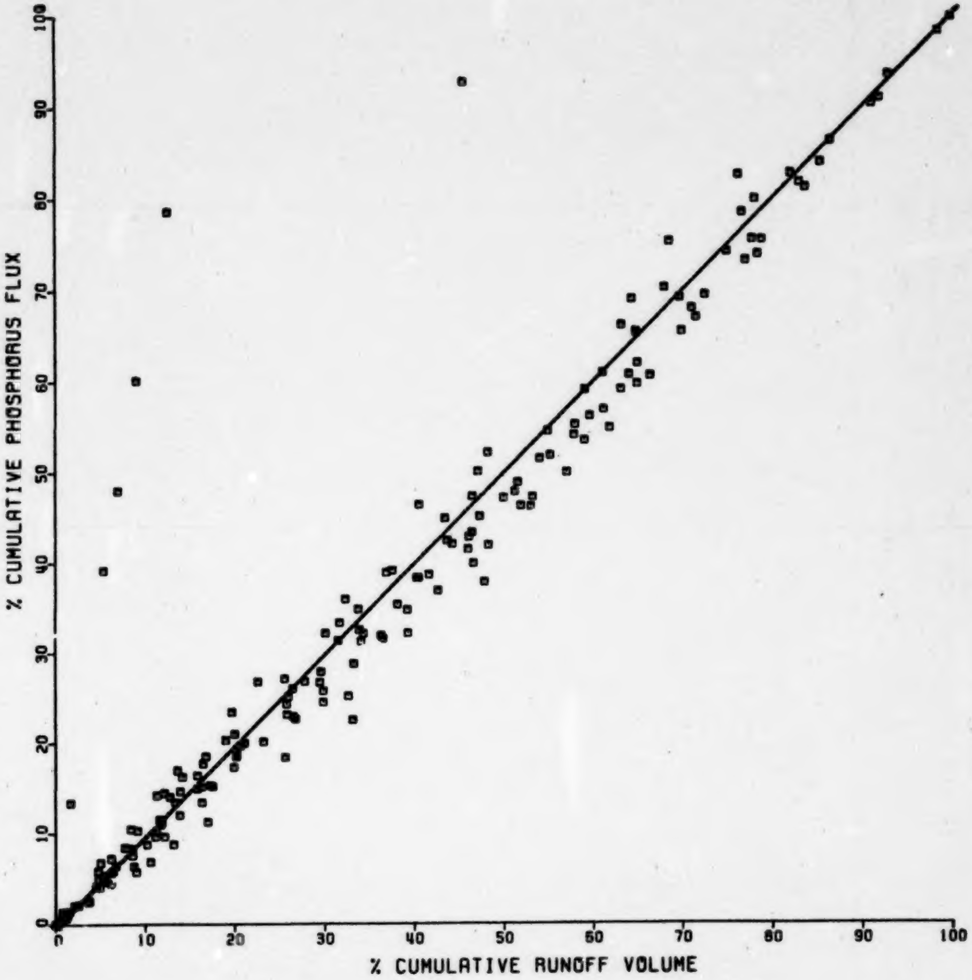

Figure D-31. Phosphorus flux scatter plot for all discrete samples in dormant season selected runoff events from WS 129 during study period.

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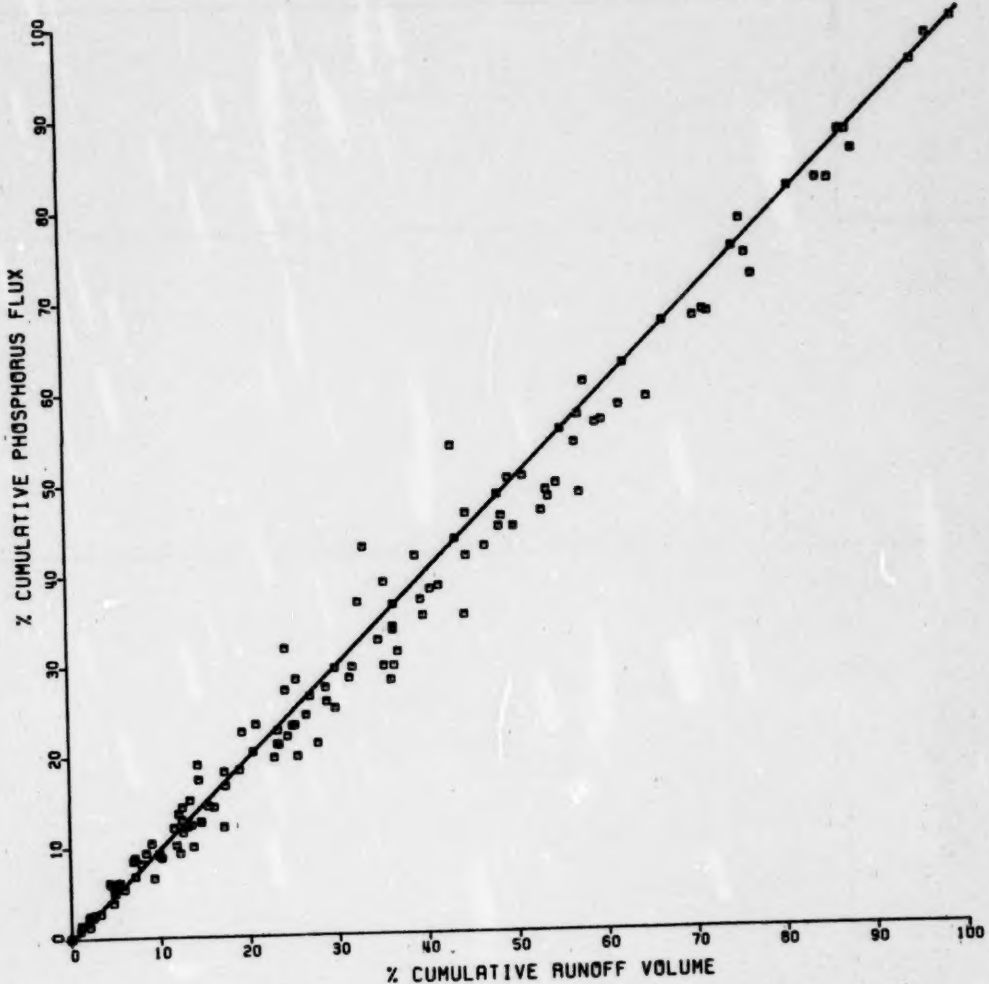

Figure D-32. Phosphorus flux scatter plot for all discrete samples in growing season selected runoff events from WS 129 during study period.

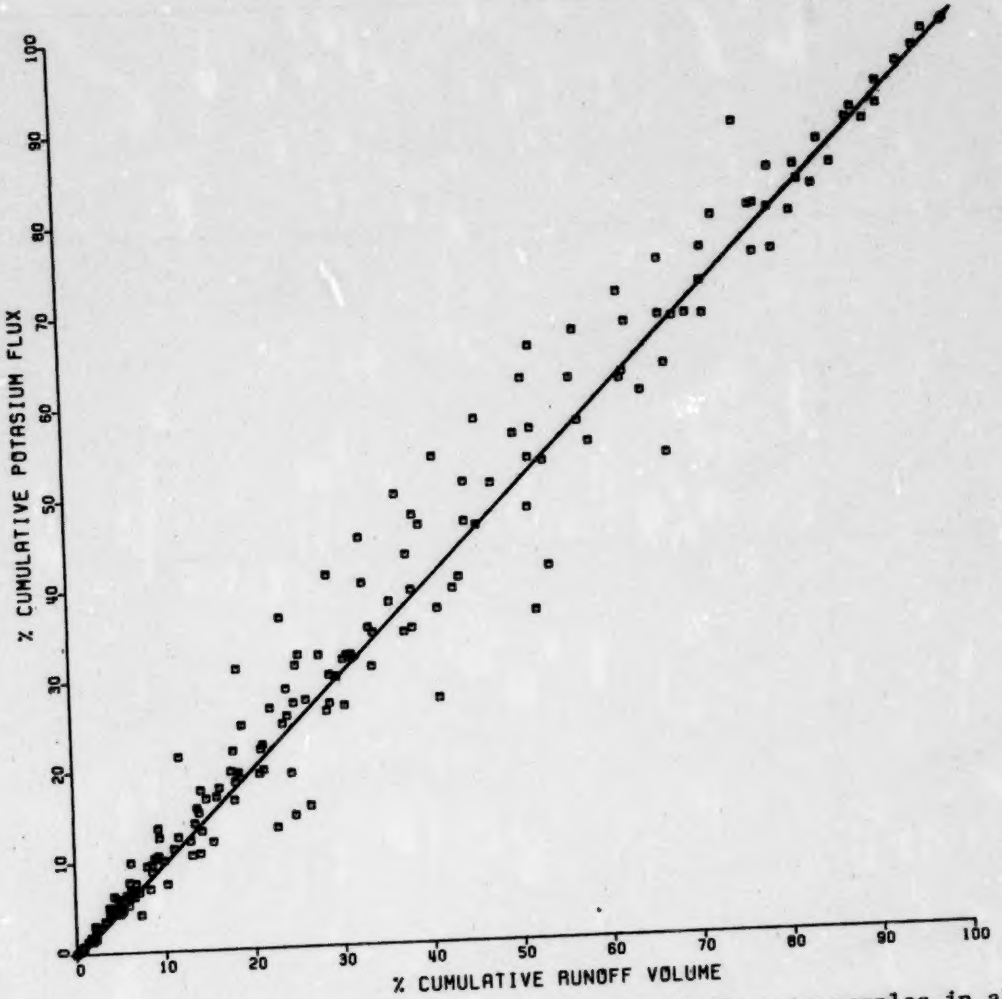

Figure D-33. Potassium flux scatter plot for all discrete samples in all selected runoff events from WS 106 during study period.

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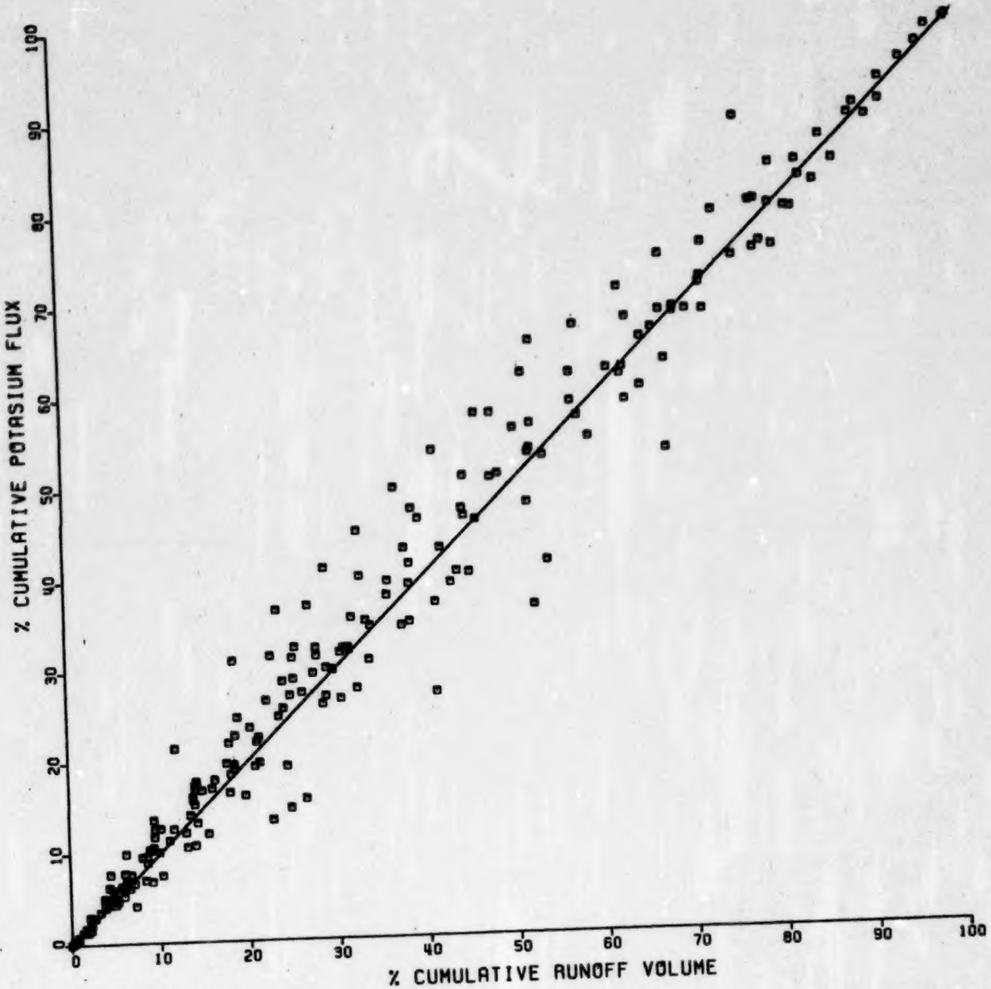

Figure D-34. Potassium flux scatter plot for all discrete samples in dormant season selected runoff events from WS 106 during study period.

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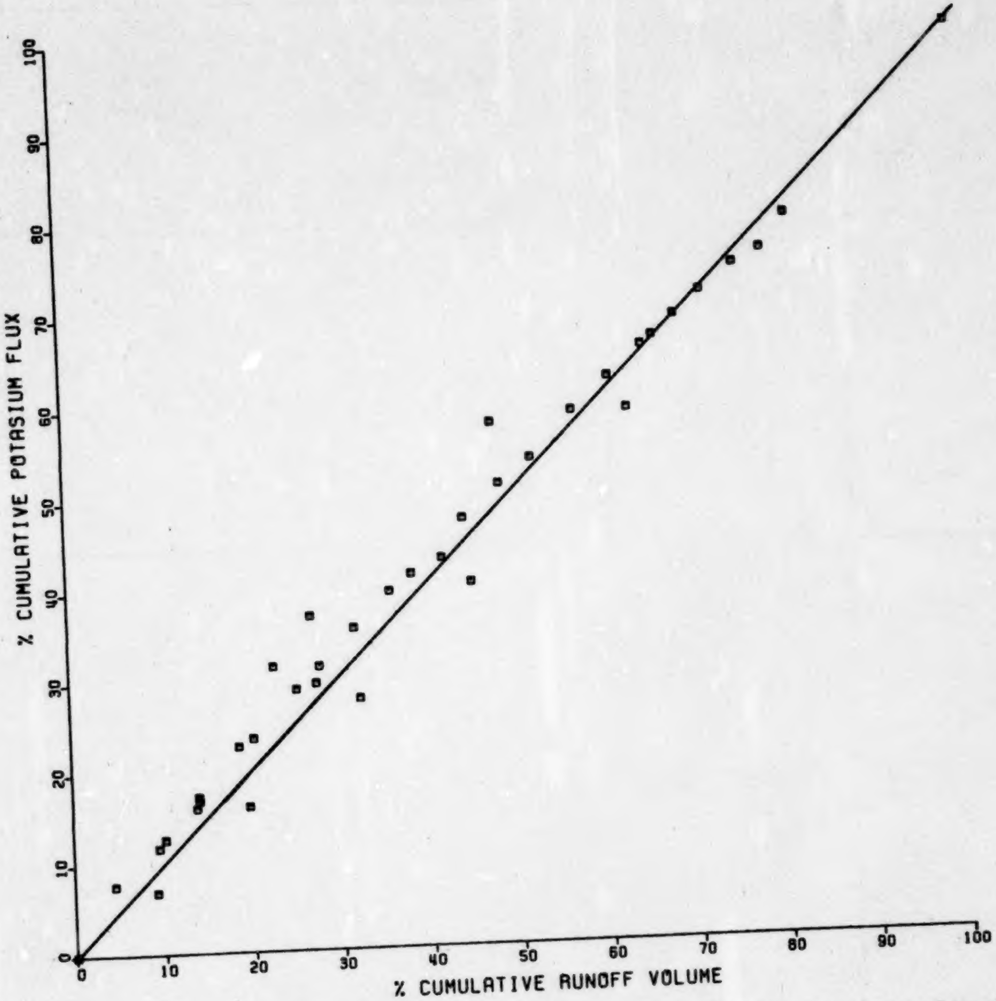

Figure D-35. Potassium flux scatter plot for all discrete samples in growing season selected runoff events from WS 106 during study period.

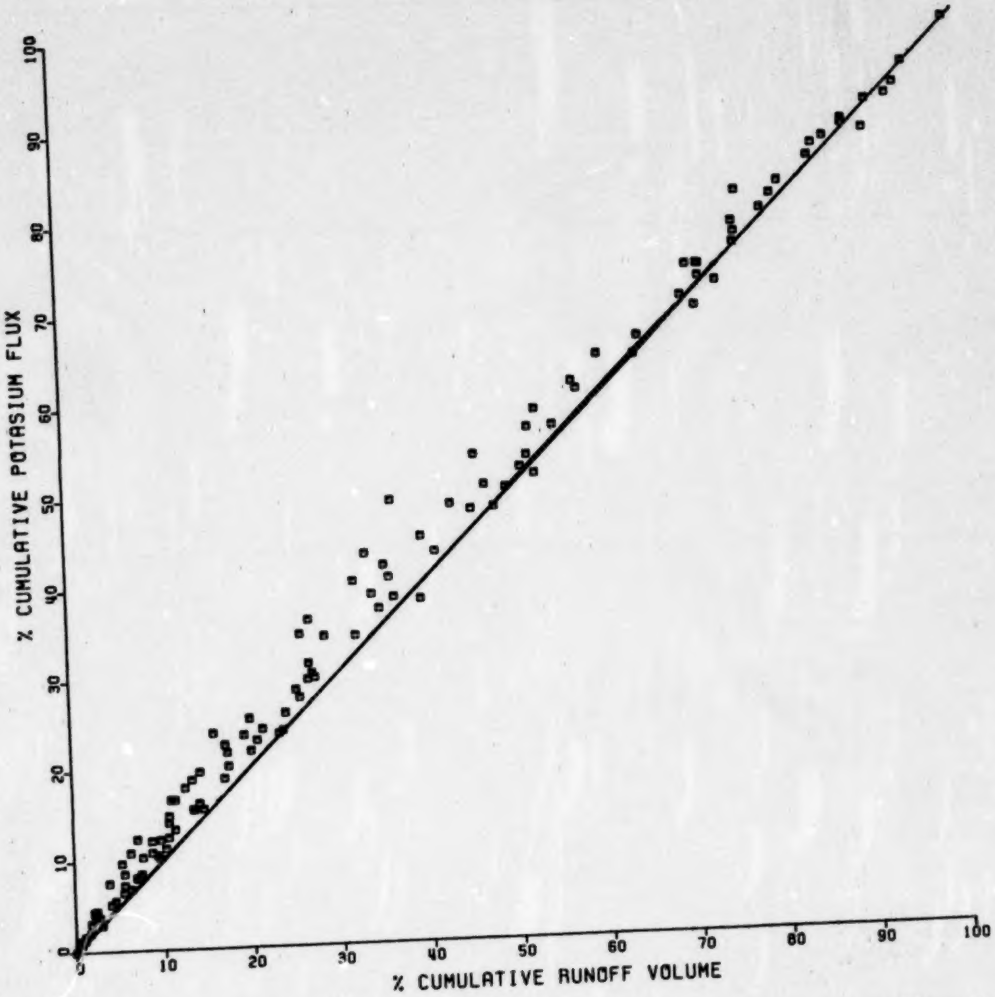

Figure D-36. Potassium flux scatter plot for all discrete samples in all selected runoff events from WS 110 during study period.

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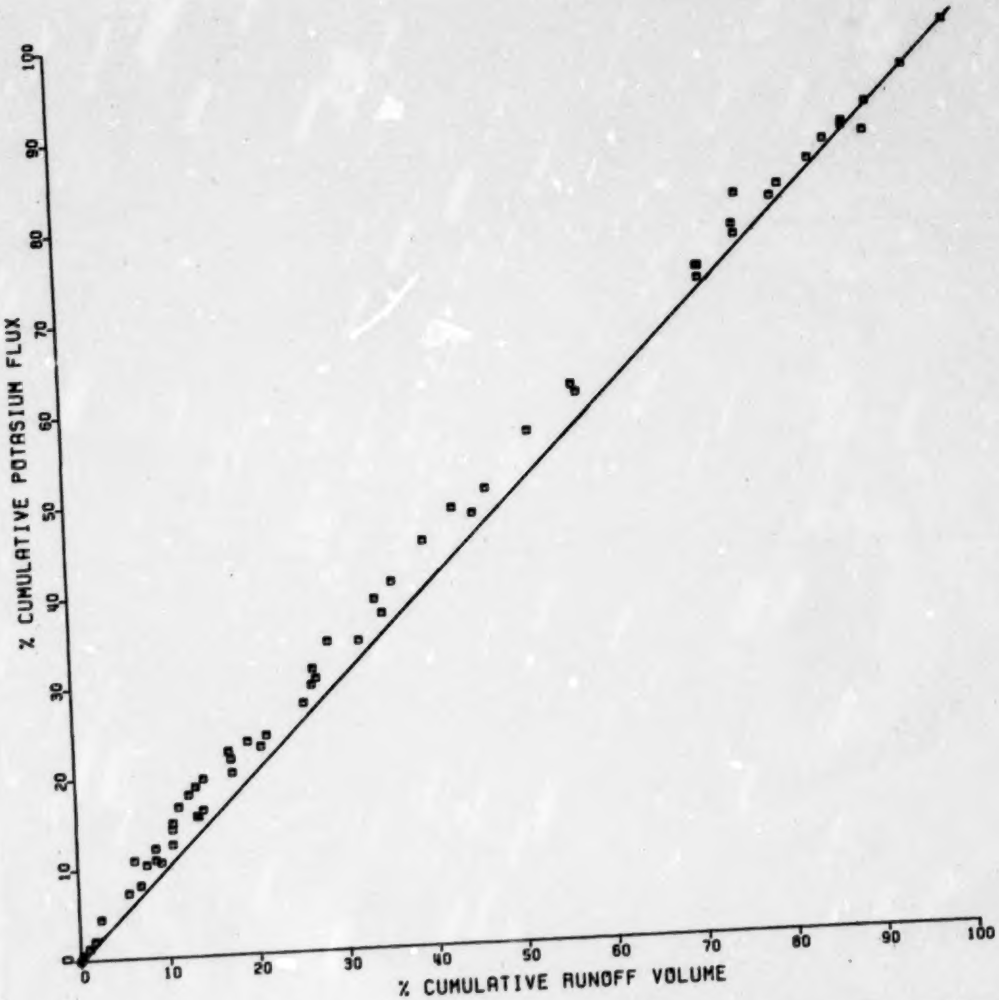

Figure D-37. Potassium flux scatter plot for all discrete samples in dormant season selected runoff events from WS 110 during study period.

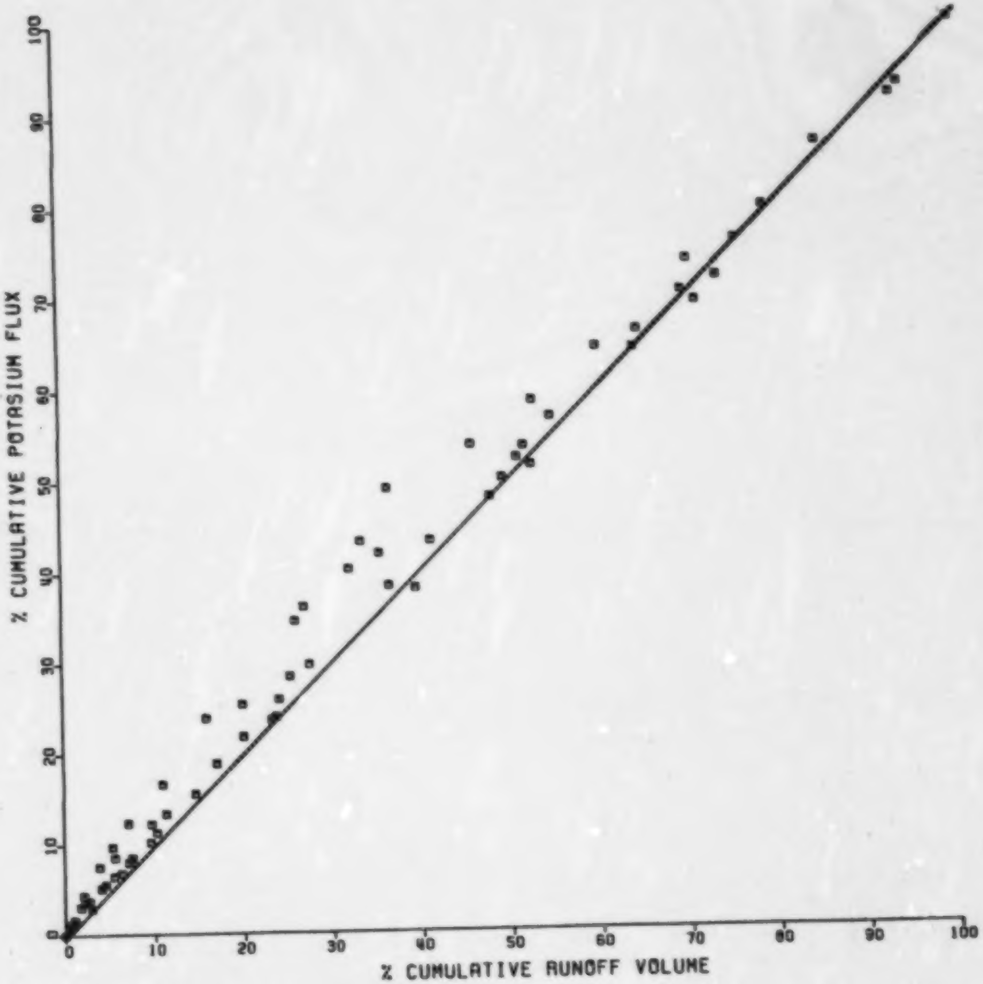

Figure D-38. Potassium flux scatter plot for all discrete samples in growing season selected runoff events from WS 110 for study period.

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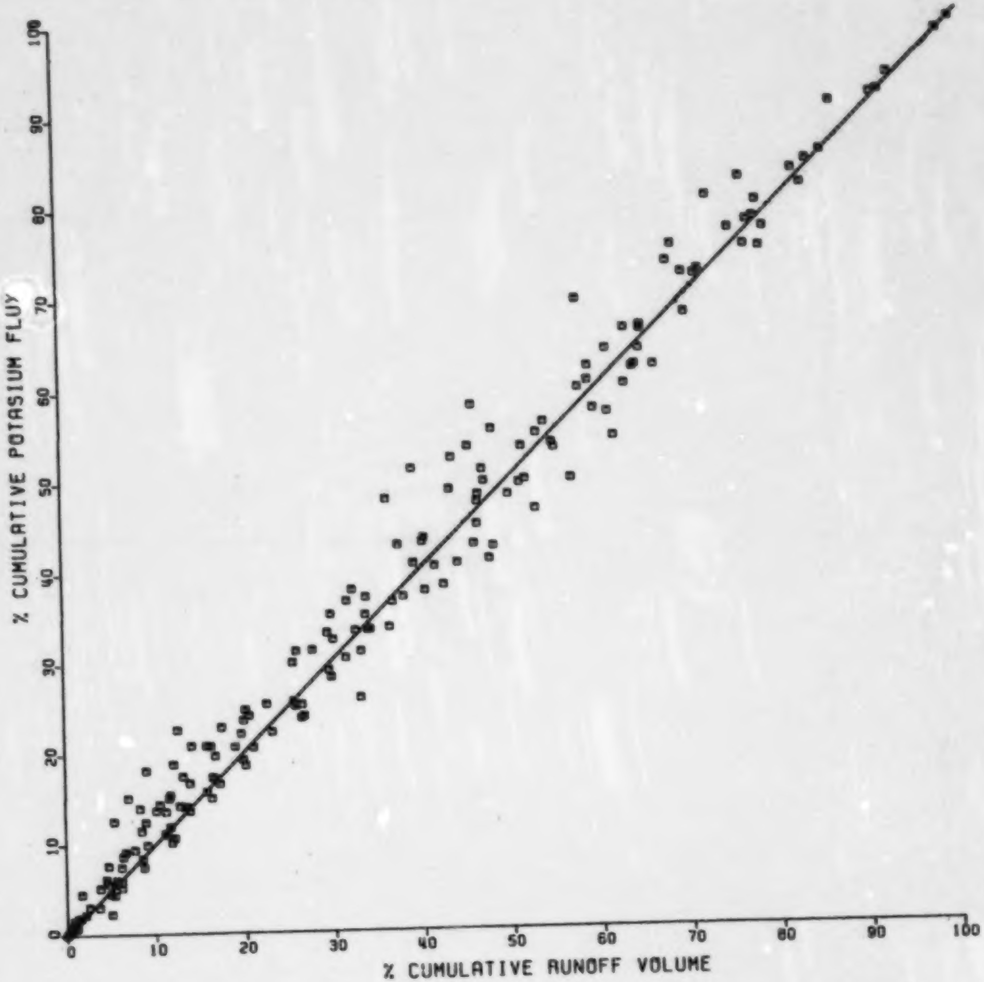

Figure D-39. Potassium flux scatter plot for all discrete samples in dormant season selected runoff events from WS 129 during study period.

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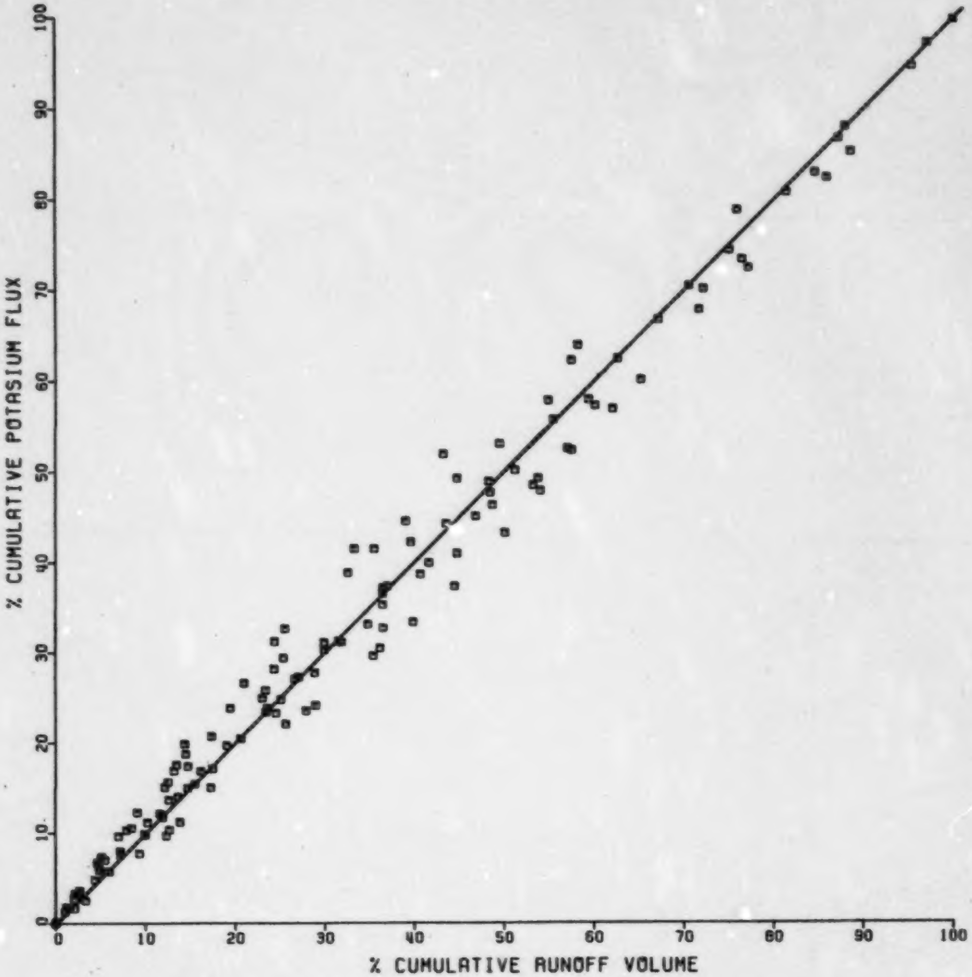

Figure D-40. Potassium flux scatter plot for all discrete samples in growing season selected runoff events from WS 129 during study period.

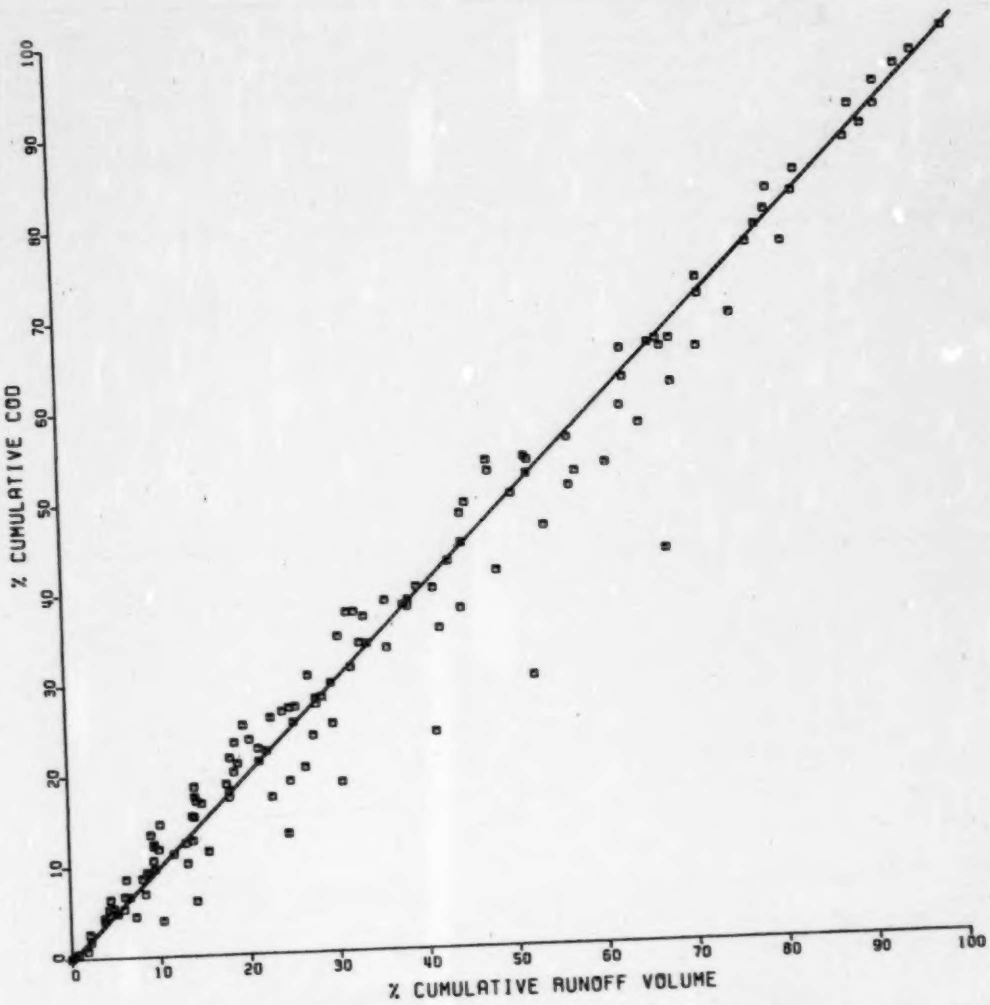

Figure D-41. Chemical oxygen demand flux scatter plot for all discrete samples in all selected runoff events from WS 106 during study period.

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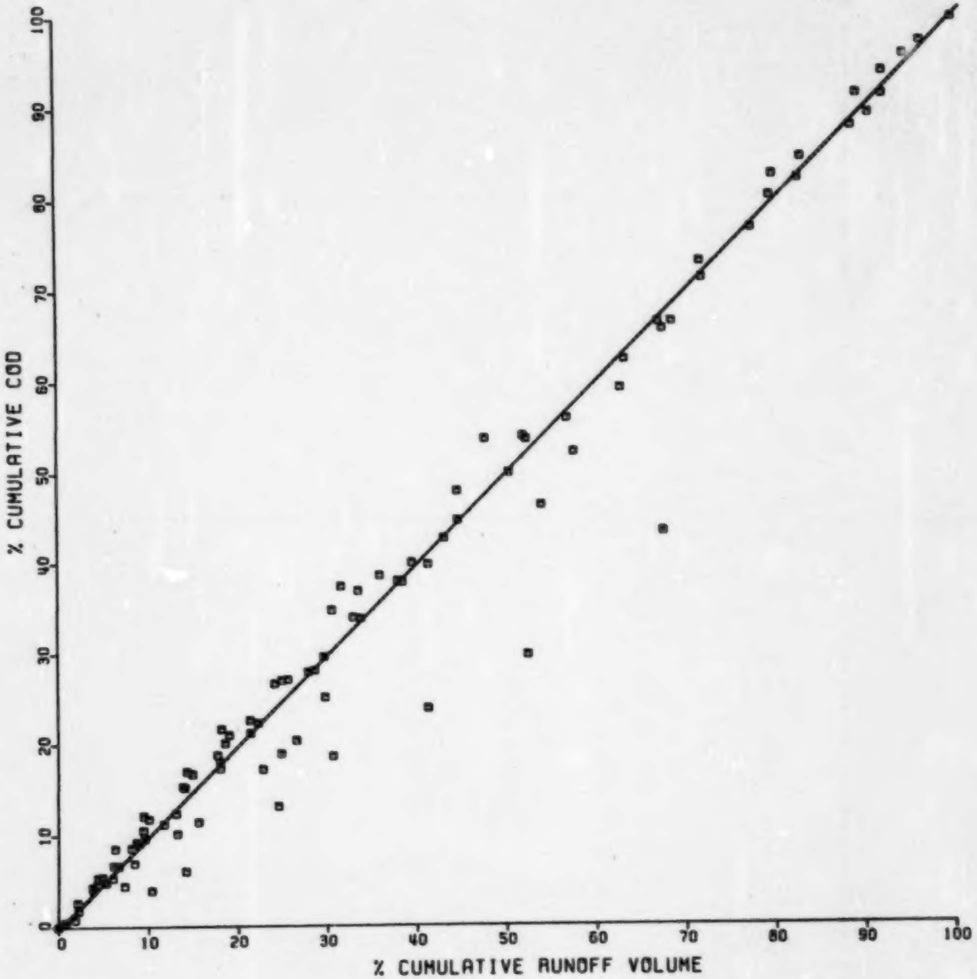

Figure D-42. Chemical oxygen demand flux scatter plot for all discrete samples in dormant season selected runoff events from WS 106 during study period.

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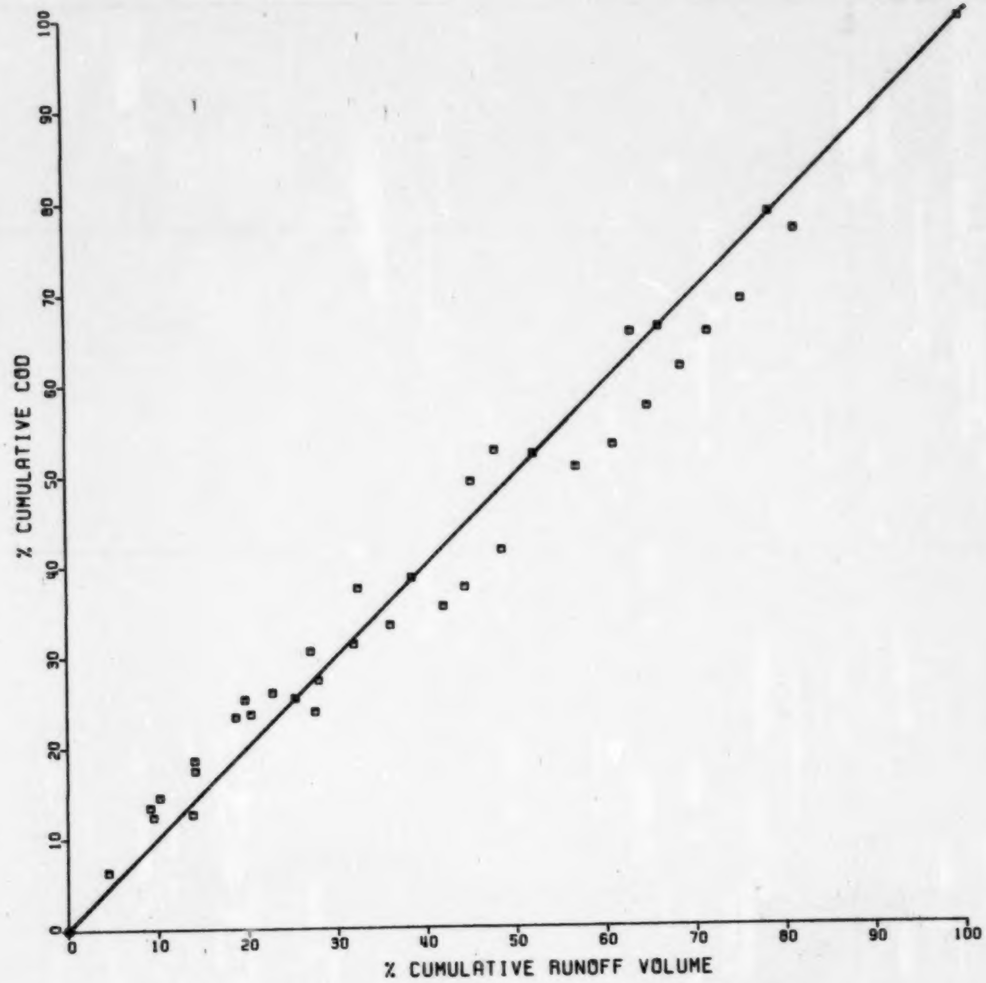

Figure D-43. Chemical oxygen demand flux scatter plot for all discrete samples in growing season selected runoff events from WS 106 during study period.

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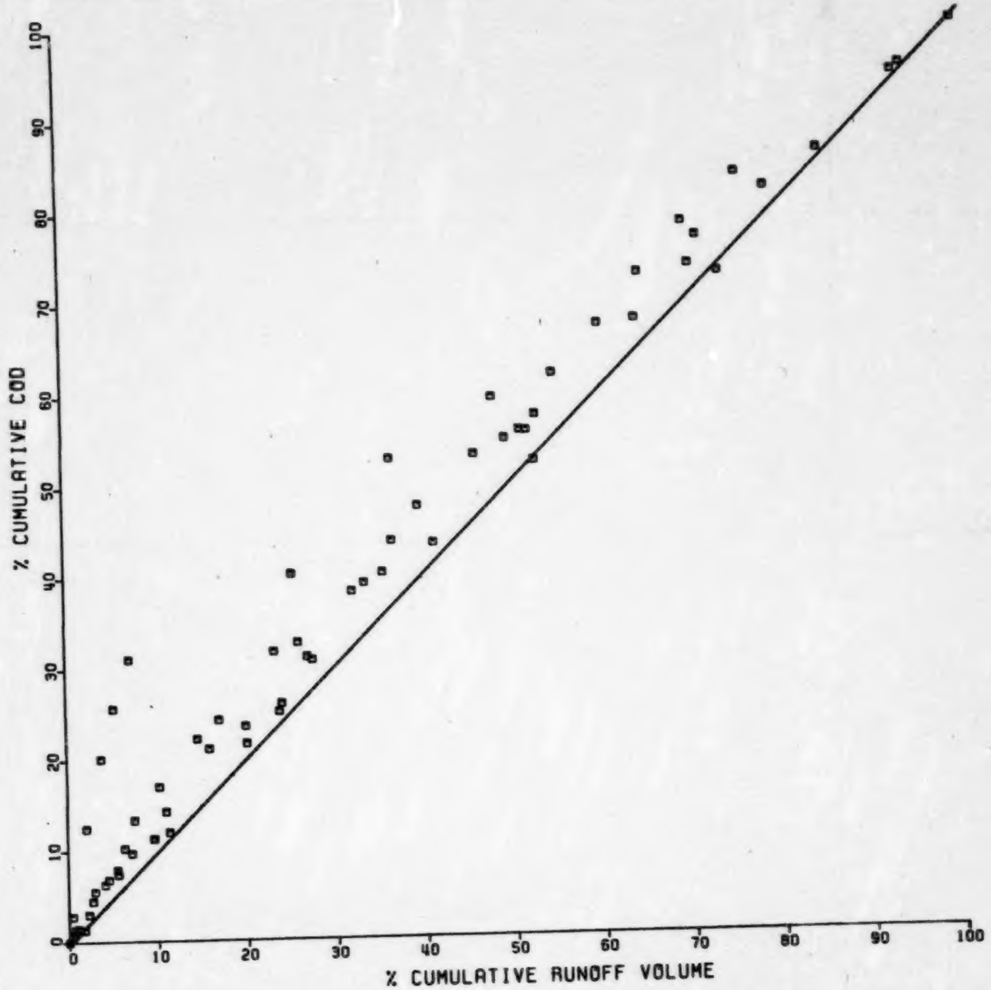

Figure D-44. Chemical oxygen demand flux scatter plot for all discrete samples in all selected runoff events from WS 110 during study period.

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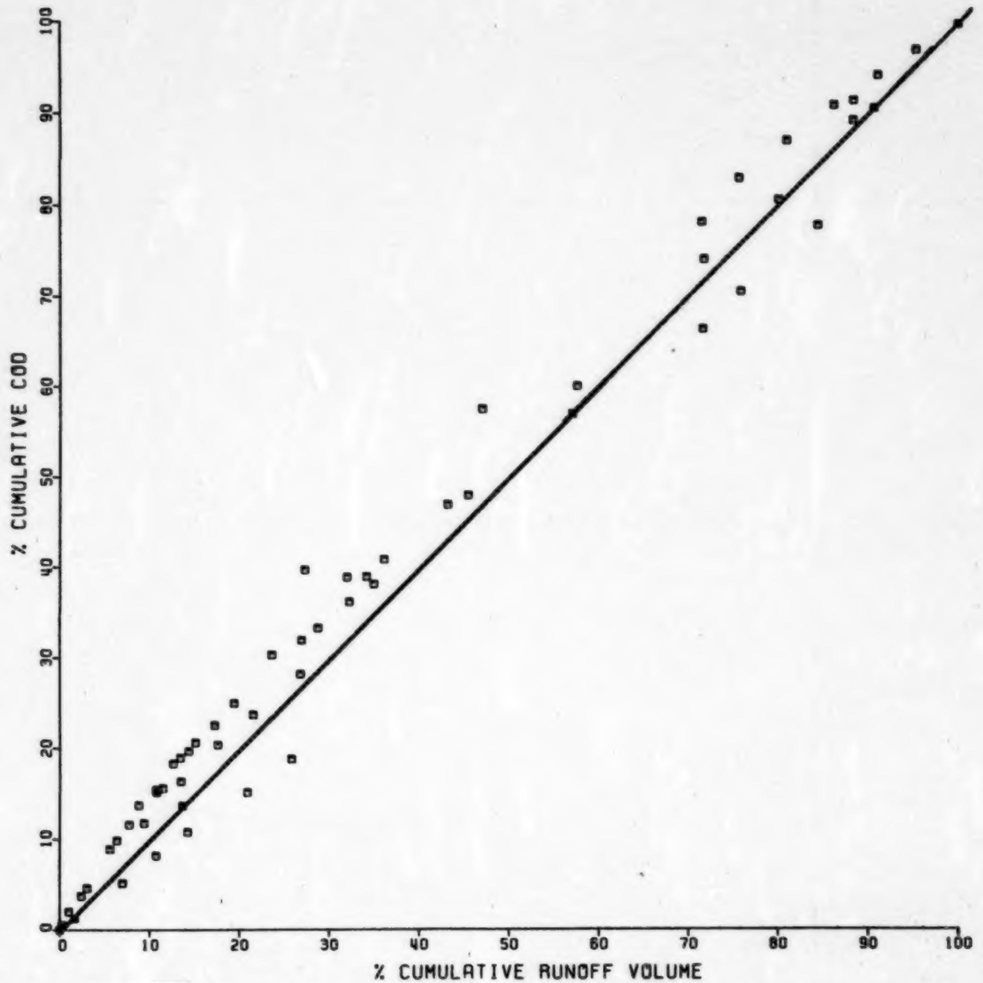

Figure D-45. Chemical oxygen demand flux scatter plot for all discrete samples in dormant season selected runoff events from WS 110 durind study period.

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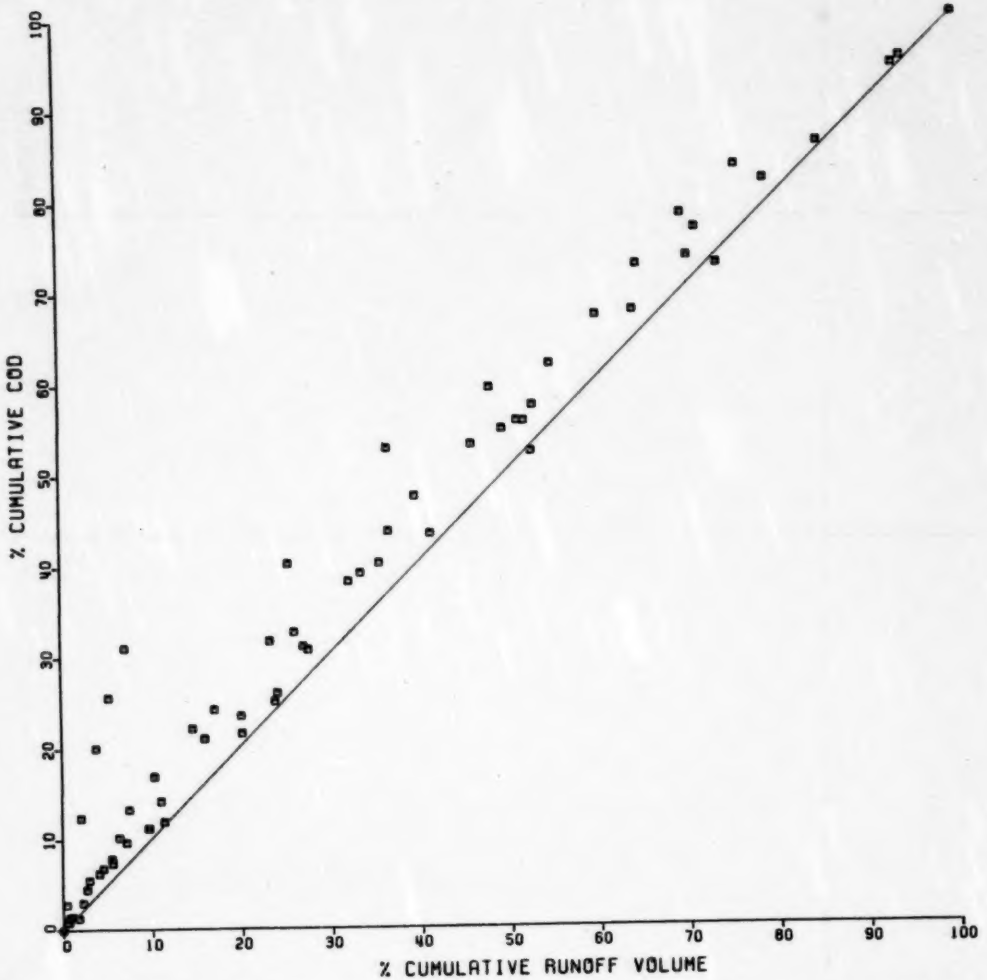

Figure D-46. Chemical Oxygen demand flux scatter plot for all discrete samples in growing season selected runoff events from WS 110 during study period.

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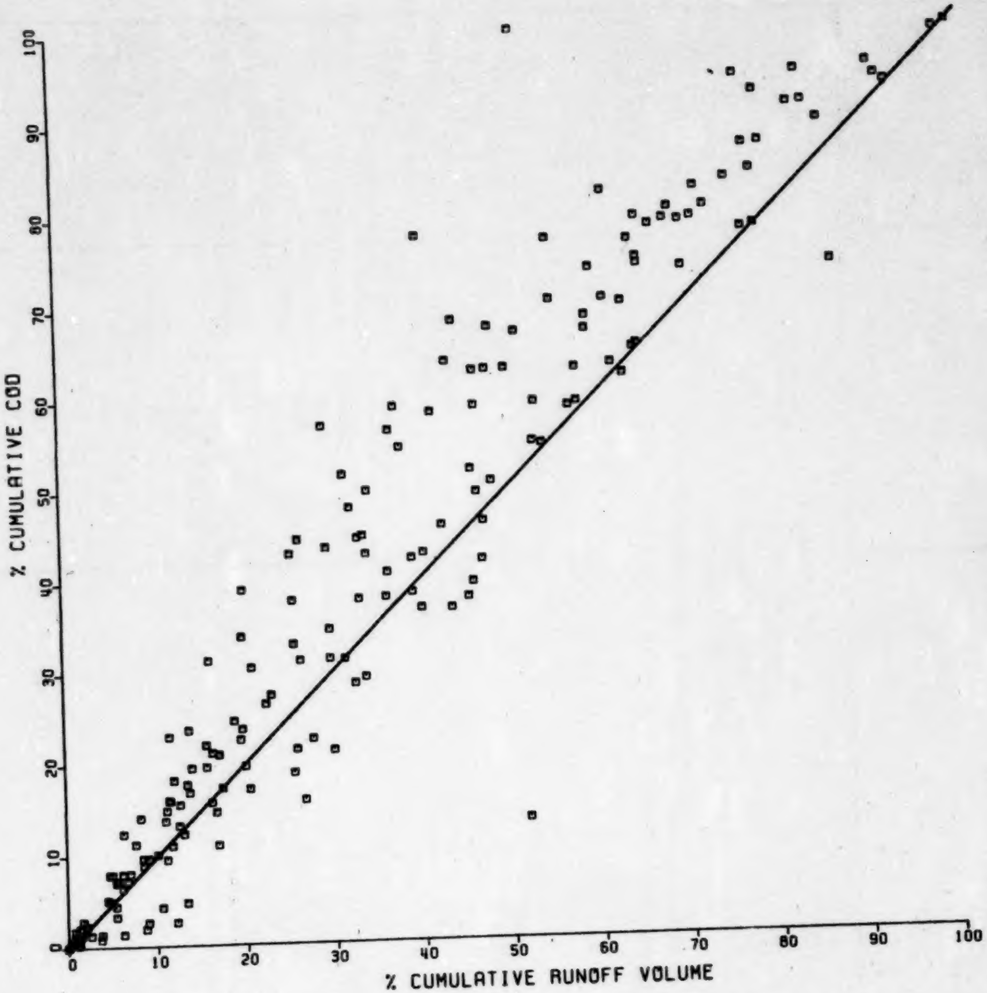

Figure D-47. Chemical oxygen demand flux scatter plot for all discrete samples in dormant season selected runoff events from WS 129 during study period.

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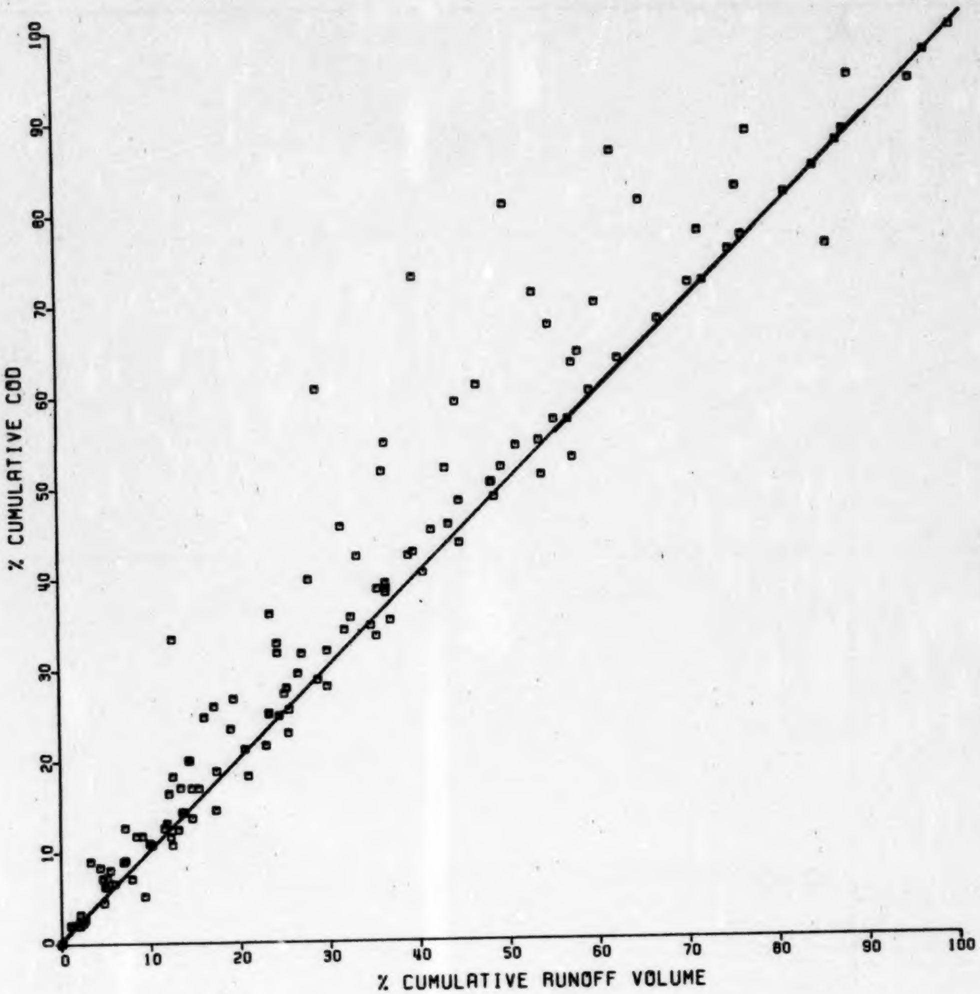

Figure D-48. Chemical oxygen demand flux scatter plot for all discrete samples in growing season selected frunoff events from WS 129 during study period.

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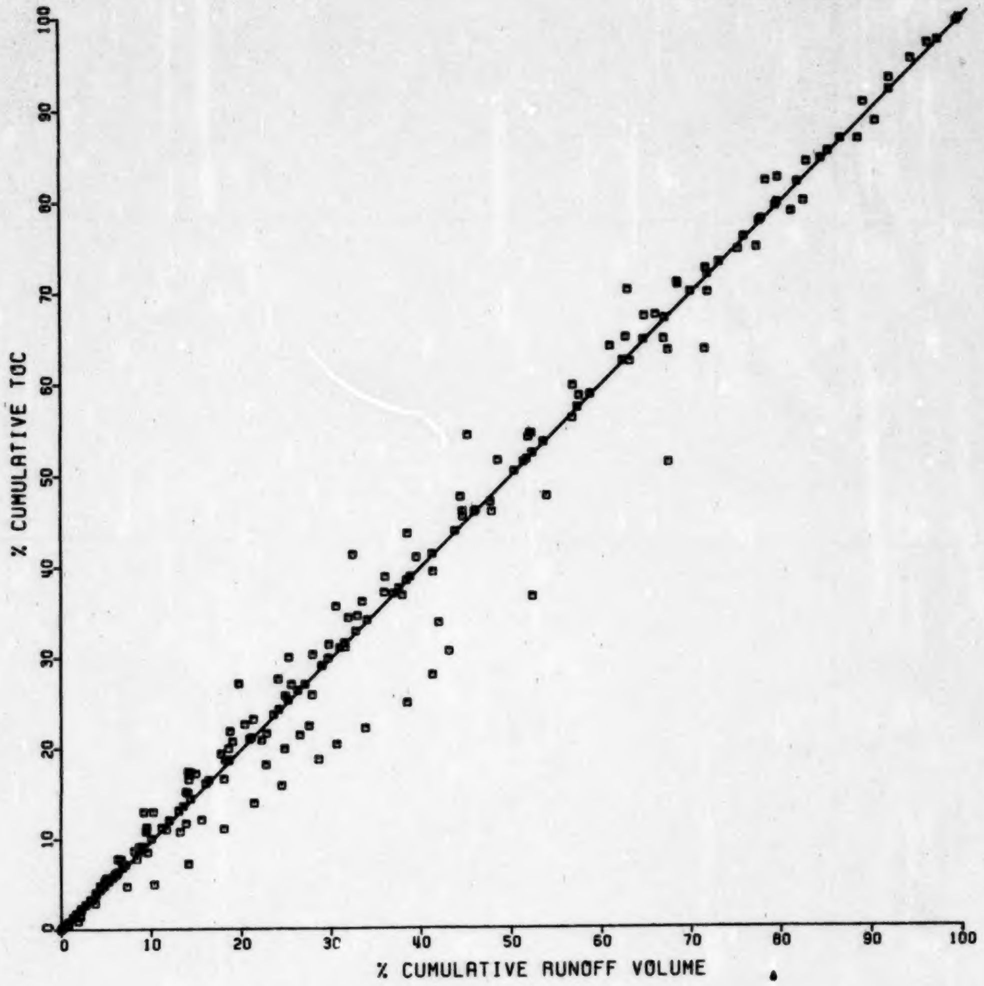

Figure D-49. Total organic carbon flux scatter plot for all discrete samples in all selected runoff events from WS 106 during study period.

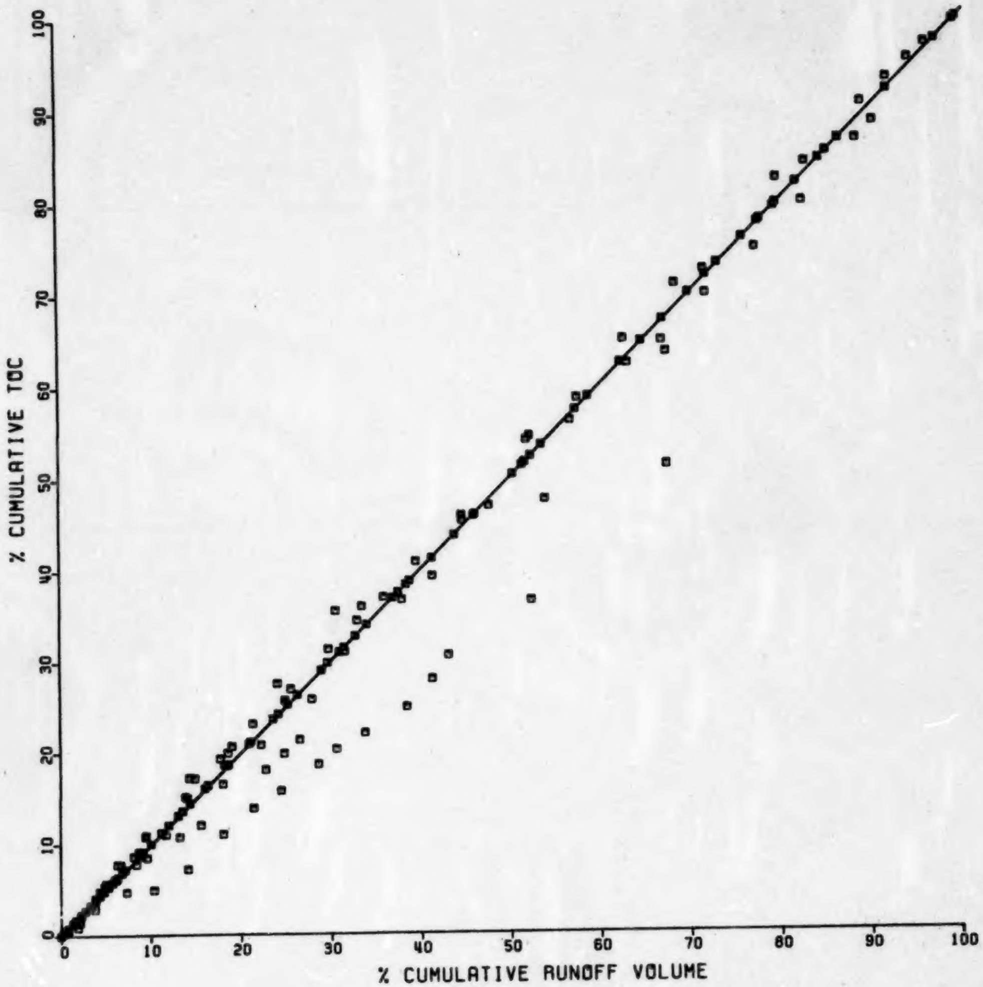

Figure D-50. Total organic carbon flux scatter plot for all discrete samples in dormant season selected runoff events from WS 106 during study period.

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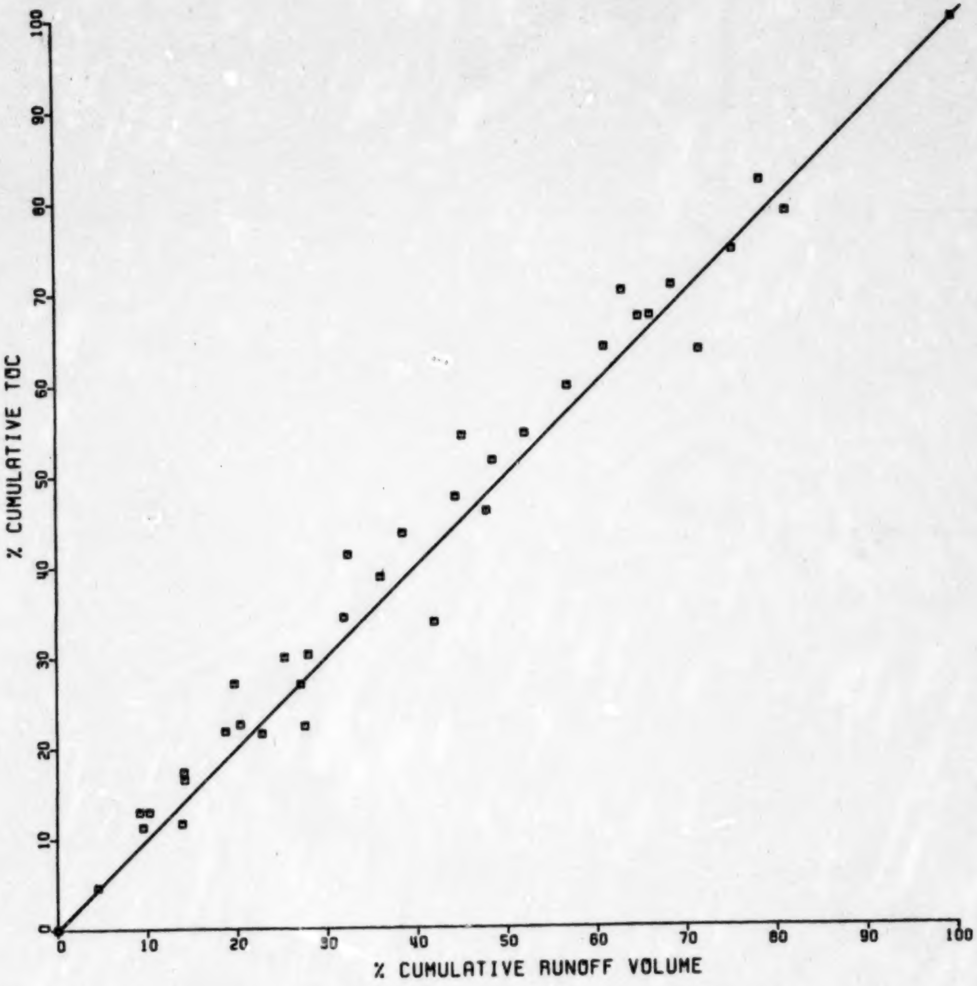

Figure D-51. Total organic carbon flux scatter plot for all discrete samples in growing season selected runoff events from WS 106 during study period.

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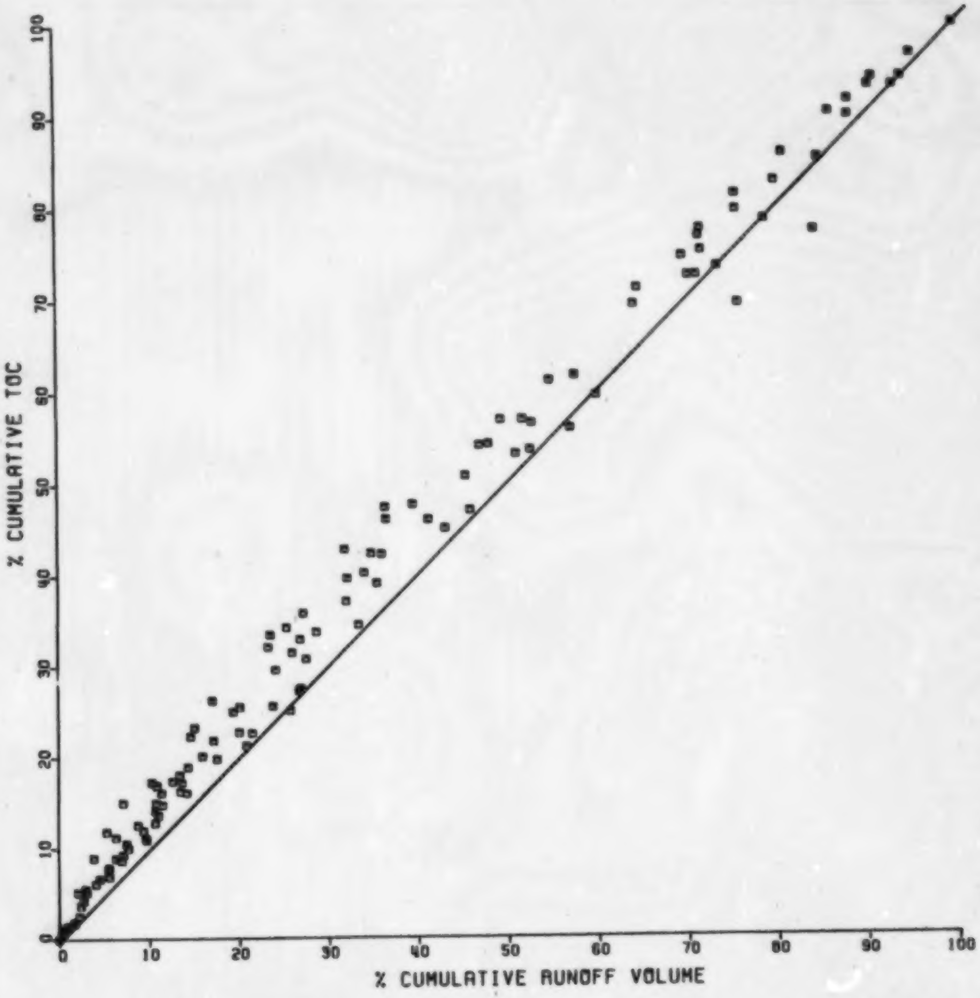

Figure D-52. Total organic carbon flux scatter plot for all discrete samples in all selected runoff events from WS 110 during study period.

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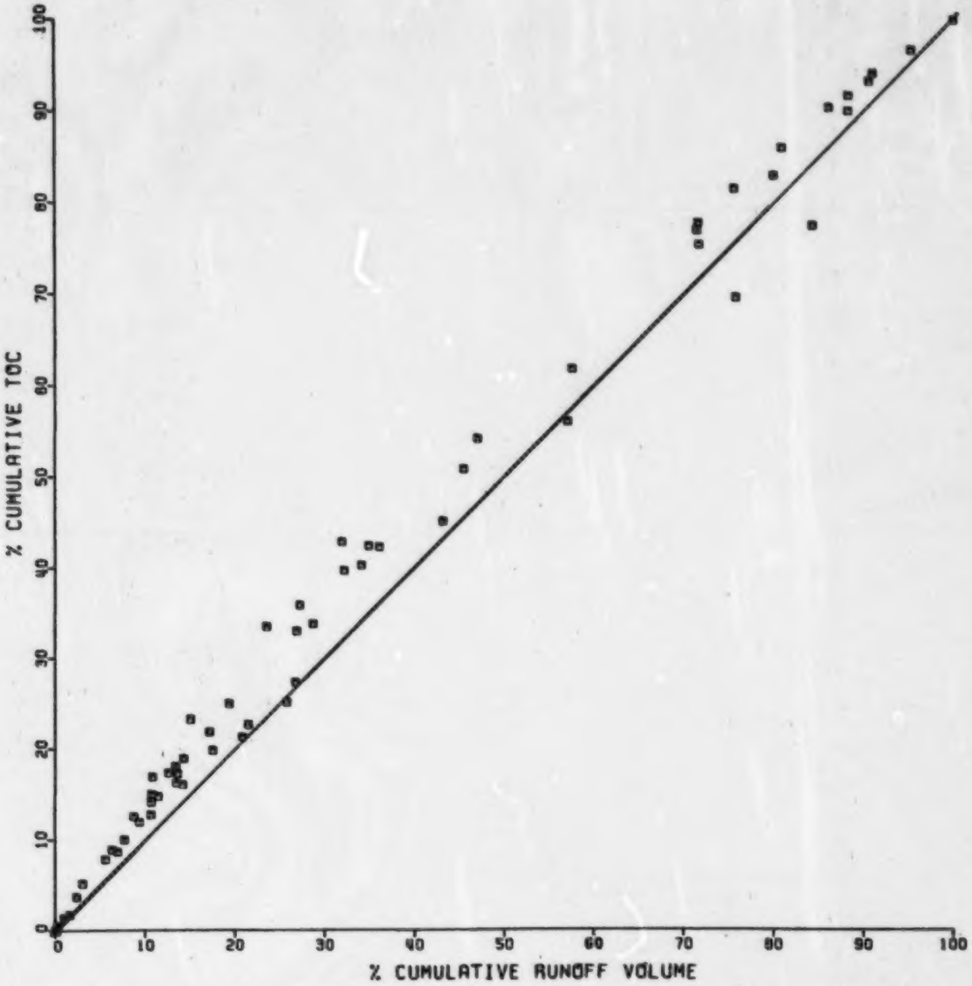

Figure D-53. Total organic carbon flux scatter plot for all discrete samples in dormant season selected runoff events from WS 110 during study period.

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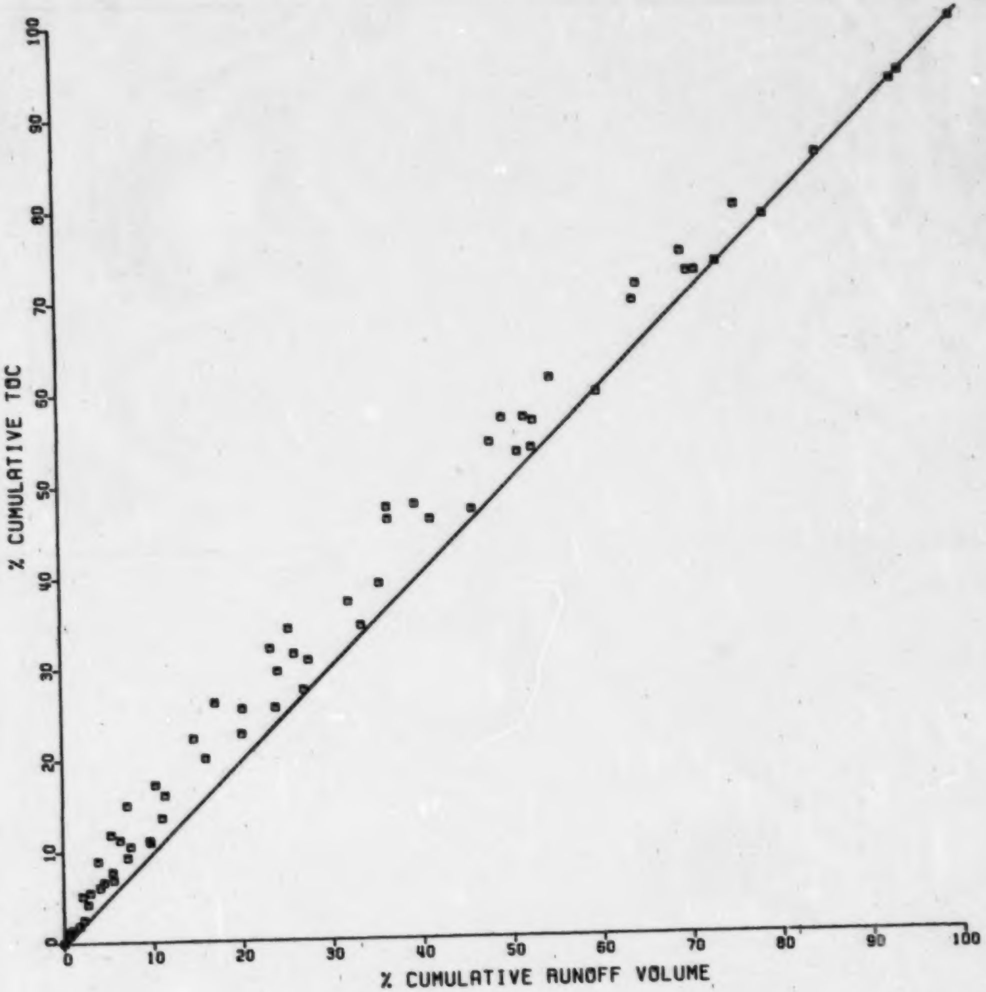

Figure D-54. Total organic carbon flux scatter plot for all discrete samples in growing season selected runoff events from WS 110 for study period.

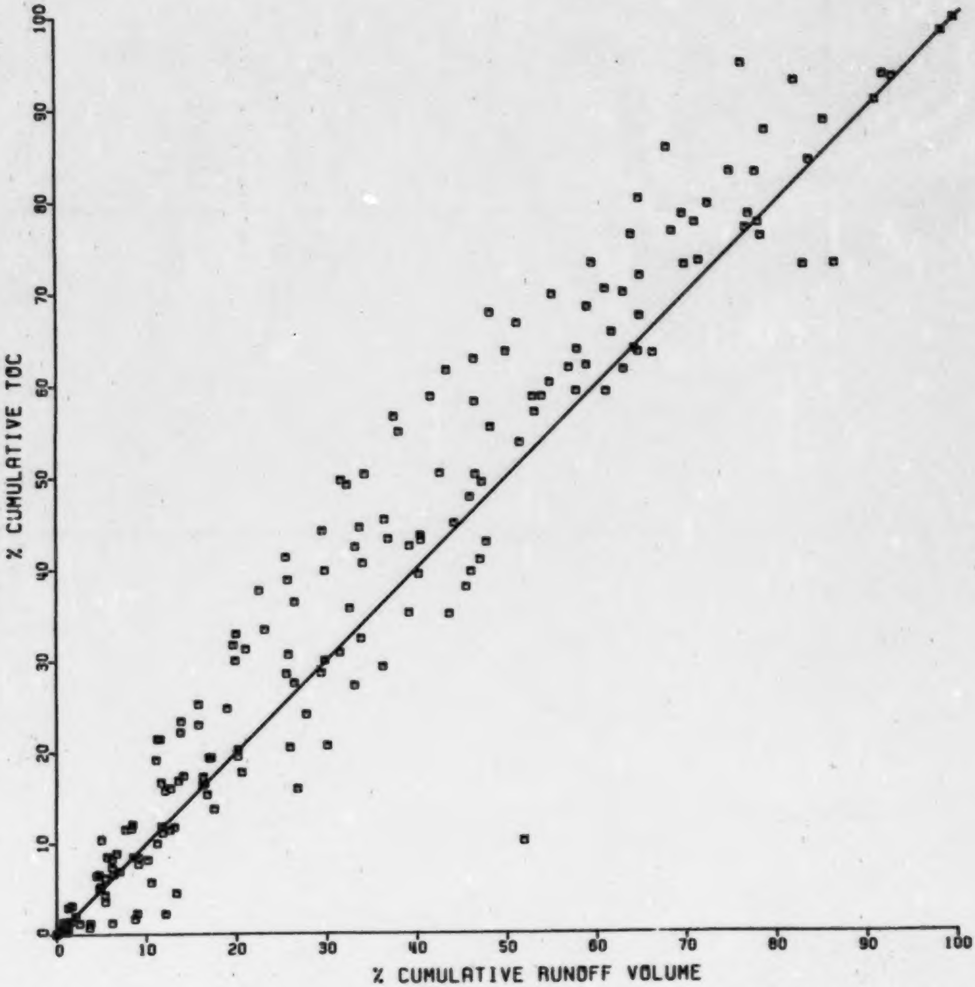

Figure D-55. Total organic carbon flux scatter plot for all discrete samples in dormant season selected runoff events from WS 129 during study period.

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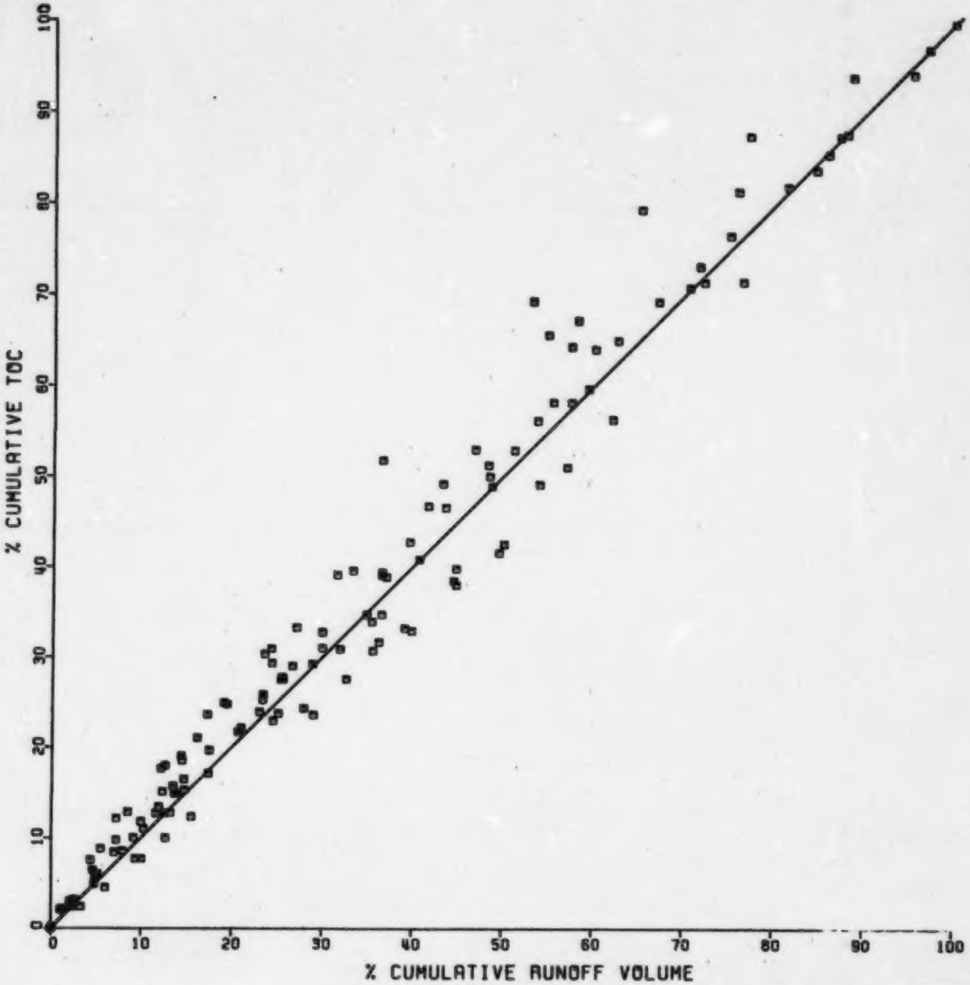

Figure D-56. Total organic carbon flux scatter plot for all discrete samples in growing season selected runoff events from WS 129 during study period.

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APPENDIX E

COMPUTER PROCEDURE FOR CALCULATING CONFIDENCE INTERVALS OF NUTRIENT FLUXES

The SAS computer package was used to determine the mean and standard deviation for each separate data grouping. They were in turn used to calculate the confidence intervals at specific points within the runoff (e.g., 10%, 25%, 50%, 75% and 90%). An example of the computer output is shown in Table E-1.

The confidence intervals were then used to determine if the nutrients came off at an ED rate, an MD rate or an LD rate. An MD was when the nutrient mass came off in direct proportion to the runoff volume (e.g. when 25% of the runoff volume had occurred, so had 25% of the nutrient flux). An ED was when the nutrient mass came off ahead of the runoff volume (e.g. when 25% of the runoff volume had occurred, 40% of the nutrient also had). LD was when the nutrient mass lagged behind the runoff volume (e.g. at 25% of the runoff volume, 10% of the nutrient had come off). At least three of the five points at the 10%, 25%, 50%, 75% or 90% of the cumulative runoff volumes had to be either MD, ED or LD for the whole data group to be classified into that delivery category.

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TABLE E-1. EXAMPLE OF COMPUTER OUTPUT FROM THE STATISTICAL ANALYSIS SYSTEM (SAS) PACKAGE

Variable	N	Mean	Standard deviation	Std Dev $\sqrt{N}$	90% Confidence interval t(0.95, 10) = 1.812	95% Confidence interval t(0.975, 10) = 2.228
NT10	11	10.645	2.211	0.667	9.4-11.9	9.2-12.1
NT25	11	25.727	3.788	1.142	23.7-27.8	23.2-28.3
NT50	11	50.718	4.854	1.464	48.1-53.4	47.5-54.0
NT75	11	76.118	3.734	1.126	74.1-78.2	73.6-78.6
NT90	11	90.473	1.437	0.433	89.7-91.3	89.5-91.4

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APPENDIX F

DATA SUMMARY OF CONFIDENCE INTERVAL ANALYSES ON THE NUTRIENT FLUXES FOR WS 106, WS 110 AND WS 129

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TABLE F-1. SUMMARY OF CONFIDENCE INTERVAL ANALYSES ON THE PERCENT CUMULATIVE TOTAL NITROGEN FLUX DATA FOR WATERSHEDS 106, 110 AND 129

Data groupings	Number of events	90% onfidence interval	95% confidence interval
All Watershed Data Combined			
All Events	96	ED (0-2%)*	ED
Watershed 106			
All Events	27	MD	MD
Dormant 76-77	7	ED (0-3%)	ED
Growing 77	2	MD	MD
Dormant 77-78	4	MD	MD
Growing 78	1	--	--
Dormant 78-79	7	MD	MD
Growing 79	3	MD	MD
Dormant 79-80	3	MD	MD
Growing 77, 78 and 79	6	MD	MD
Dormant 77, 78, 79 and 80	21	ED (0-1%)	MD
Small Events	16	MD	MD
Large Events	11	MD	MD
Watershed 110			
All Events	21	ED (0-1%)	MD
Dormant 76-77	1	--	--
Growing 77	2	MD	MD
Dormant 77-78	4	MD	MD
Growing 78	3	MD	MD
Dormant 78-79	4	MD	MD
Growing 79	6	ED (0-1%)	MD
Dormant 79-80	1	--	--
Growing 77, 78 and 79	11	ED (0-2%)	ED
Dormant 77, 78, 79 and 80	10	MD	MD
Small Events	11	MD	MD
Large Events	10	MD	MD
Watershed 129			
All Events	48	ED (0-2%)	ED
Dormant 76-77	1	--	--
Growing 77	6	MD	MD
Dormant 77-78	9	MD	MD
Growing 78	4	ED (0-1%)	MD
Dormant 78-79	10	ED (0-3%)	ED
Growing 79	12	ED (0-3%)	ED
Dormant 79-80	6	MD	MD
Growing 77, 78 and 79	22	ED (0-2%)	ED
Dormant 77, 78, 79 and 80	26	ED (0-1%)	MD
Small Events	30	ED (1-2%)	ED
Large Events	18	MD	MD

*MD = matched delivery of nutrients with runoff; ED = early delivery; LD = late delivery. The percentage points listed in parentheses are the range by which the observed nutrient flux fell outside the confidence interval.

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TABLE F-2. SUMMARY OF CONFIDENCE INTERVAL ANALYSES ON THE PERCENT CUMULATIVE MINERAL NITROGEN FLUX DATA FOR WATERSHEDS 106, 110 AND 129

Data groupings	Number of events	90% confidence interval	95% confidence interval
All Watershed Data Combined			
All Events	96	ED (0-3%)*	ED
Watershed 106			
All Events	27	ED (0-1%)	MD
Dormant 77	7	ED (1-2%)	--
Growing 77	2	MD	MD
Dormant 77-78	4	MD	MD
Growing 78	1	--	--
Dormant 78-79	7	MD	MD
Growing 79	3	MD	MD
Dormant 79-80	3	MD	MD
Growing 77, 78 and 79	6	MD	MD
Dormant 77, 78, 79 and 80	21	ED (0-1%)	MD
Small Events	16	ED (0-2%)	MD
Large Events	11	MD	MD
Watershed 110			
All Events	21	ED (0-2%)	MD
Dormant 76-77	1	--	--
Growing 77	2	MD	MD
Dormant 77-78	4	MD	MD
Growing 78	3	MD	MD
Dormant 78-79	4	MD	MD
Growing 79	6	MD	MD
Dormant 79-80	1	--	--
Growing 77, 78 and 79	11	MD	MD
Dormant 77, 78, 79 and 80	10	MD	MD
Small Events	11	MD	MD
Large Events	10	MD	MD
Watershed 129			
All Events	48	ED (0-3%)	ED
Dormant 76-77	1	--	--
Growing 77	6	MD	MD
Dormant 77-78	9	MD	MD
Growing 78	4	ED (0-1%)	MD
Dormant 78-79	10	ED (1-3%)	ED
Growing 79	12	ED (0-3%)	MD
Dormant 79-80	6	MD	MD
Growing 77, 78 and 79	22	MD	MD
Dormant 77, 78, 79 and 80	26	ED (0-3%)	ED
Small Events	30	ED (0-2%)	MD
Large Events	18	ED (1-3%)	ED

*MD = matched delivery of nutrients with runoff; ED = early delivery; LD = late delivery. The percentage points listed in parentheses are the range by which the observed nutrient flux fell outside the confidence interval.

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TABLE F-3. SUMMARY OF CONFIDENCE INTERVAL ANALYSES ON THE PERCENT CUMULATIVE ORGANIC NITROGEN FLUX DATA FOR WATERSHEDS 106, 110 AND 129

Data groupings	Number of events	90% confidence interval	95% confidence interval
All Watershed Data Combined			
All Events	96	ED (0-2%)*	ED
Watershed 106			
All Events	27	MD	MD
Dormant 76-77	7	MD	MD
Growing 77	2	MD	MD
Dormant 77-78	4	MD	MD
Growing 78	1	--	--
Dormant 78-79	7	MD	MD
Growing 79	3	MD	MD
Dormant 79-80	3	MD	MD
Growing 77, 78 and 79	6	MD	MD
Dormant 77, 78, 79 and 80	21	MD	MD
Small Events	16	MD	MD
Large Events	11	MD	MD
Watershed 110			
All Events	21	ED (0-3%)	ED
Dormant 76-77	1	--	--
Growing 77	2	MD	MD
Dormant 77-78	4	MD	MD
Growing 78	3	MD	MD
Dormant 78-79	4	MD	MD
Growing 79	6	MD	MD
Dormant 79-80	1	--	--
Growing 77, 78 and 79	11	ED (1-3%)	ED
Dormant 77, 78, 79 and 80	10	MD	MD
Small Events	11	ED (1-6%)	ED
Large Events	10	MD	MD
Watershed 129			
All Events	48	ED (1-2%)	ED
Dormant 76-77	1	--	--
Growing 77	6	MD	MD
Dormant 77-78	9	MD	MD
Growing 78	4	MD	MD
Dormant 78-79	10	MD	MD
Growing 79	12	ED (0-5%)	MD
Dormant 79-80	6	MD	MD
Growing 77, 78 and 79	22	ED (0-2%)	ED
Dormant 77, 78, 79 and 80	26	MD	MD
Small Events	30	ED (0-3%)	ED
Large Events	18	MD	MD

*MD = matched delivery of nutrients with runoff; ED = early delivery; LD = late delivery. The percentage points listed in parentheses are the range by which the observed nutrient flux fell outside the confidence interval.

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TABLE F-4. SUMMARY OF CONFIDENCE INTERVAL ANALYSES ON THE PERCENT CUMULATIVE PHOSPHORUS FLUX DATA FOR WATERSHEDS 106, 110 and 129

Data groupings	Number of events	90% confidence interval	95% confidence interval
All Watershed Data Combined			
All Events	96	MD*	MD
Watershed 106			
All Events	27	MD	MD
Dormant 76-77	7	MD	MD
Growing 77	2	MD	MD
Dormant 77-78	4	MD	MD
Growing 78	1	--	--
Dormant 78-79	7	LD (2-0%)	MD
Growing 79	3	MD	MD
Dormant 79-80	3	MD	MD
Growing 77, 78 and 79	6	MD	MD
Dormant 77, 78, 79 and 80	21	MD	MD
Small Events	16	MD	MD
Large Events	11	MD	MD
Watershed 110			
All Events	21	MD	MD
Dormant 76-77	1	--	--
Growing 77	2	MD	MD
Dormant 77-78	4	MD	MD
Growing 78	3	MD	MD
Dormant 78-79	4	MD	MD
Growing 79	6	MD	MD
Dormant 79-80	1	--	--
Growing 77, 78 and 79	11	MD	MD
Dormant 77, 78, 79 and 80	10	MD	MD
Small Events	11	MD	MD
Large Events	10	MD	MD
Watershed 129			
All Events	48	MD	MD
Dormant 76-77	1	--	--
Growing 77	6	MD	MD
Dormant 77-78	9	MD	MD
Growing 78	4	MD	MD
Dormant 78-79	10	MD	MD
Growing 79	12	MD	MD
Dormant 79-80	6	MD	MD
Growing 77, 78 and 79	22	MD	MD
Dormant 77, 78, 79 and 80	26	MD	MD
Small Events	30	LD (1-0%)	LD
Large Events	18	MD	MD

*MD = matched delivery of nutrients with runoff; ED = early delivery; LD = late delivery. The percentage points listed in parentheses are the range by which the observed nutrient flux fell outside the confidence interval.

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TABLE F-5. SUMMARY OF CONFIDENCE INTERVAL ANALYSES ON THE PERCENT CUMULATIVE POTASSIUM FLUX DATA FOR WATERSHEDS 106, 110 AND 129

Data groupings	Number of events	90% confidence interval	95% confidence interval
All Watershed Data Combined			
All Events	96	ED (0-1%)*	ED
Watershed 106			
All Events	27	MD	MD
Dormant 76-77	7	MD	MD
Growing 77	2	MD	MD
Dormant 77-78	4	MD	MD
Growing 78	1	--	--
Dormant 78-79	7	MD	MD
Growing 79	3	MD	MD
Dormant 79-80	3	MD	MD
Growing 77, 78 and 79	6	MD	MD
Dormant 77, 78, 79 and 80	21	MD	MD
Small Events	16	MD	MD
Large Events	11	MD	MD
Watershed 110			
All Events	21	ED (0-3%)	ED
Dormant 76-77	1	--	--
Growing 77	2	ED (0-1%)	MD
Dormant 77-78	4	ED (0-2%)	MD
Growing 78	3	MD	MD
Dormant 78-79	4	ED (0-2%)	ED
Growing 79	6	MD	MD
Dormant 79-80	1	--	--
Growing 77, 78 and 79	11	ED (0-2%)	ED
Dormant 77, 78, 79 and 80	10	ED (0-3%)	ED
Small Events	11	ED (0-2%)	ED
Large Events	10	ED (0-3%)	ED
Watershed 129			
All Events	48	MD	MD
Dormant 76-77	1	--	--
Growing 77	6	MD	MD
Dormant 77-78	9	MD	MD
Growing 78	4	MD	MD
Dormant 78-79	10	MD	MD
Growing 79	12	MD	MD
Dormant 79-80	6	MD	MD
Growing 77, 78 and 79	22	MD	MD
Dormant 77, 78, 79 and 80	26	ED (0-1%)	MD
Small Events	30	MD	MD
Large Events	18	ED (0-2%)	ED

*MD = matched delivery of nutrients with runoff; ED = early delivery; LD = late delivery. The percentage points listed in parentheses are the range by which the observed nutrient flux fell outside the confidence interval.

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APPENDIX G

NUTRIENT FLUX AND CONCENTRATION DATA FOR RUNOFF EVENTS SELECTED FOR PERIODIC ANALYSIS

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TABLE G-1. NUTRIENT FLUX DATA FOR WATERSHED 106 (SELECTED EVENTS)*

Gregorian date	Wheel sediment (kg/ha)	Total N Flux Soluble (kg/ha)	Total N Flux Sediment (kg/ha)	Total N Flux Sed-Sol ratio	Total P Flux Soluble (kg/ha)	Total P Flux Sediment (kg/ha)	Total P Flux Sed-Sol ratio	Extract K Flux Soluble (kg/ha)	Extract K Flux Sediment (kg/ha)	Extract K Flux Sed-Sol ratio
2/12/77	0.970	0.552	0.007	0.012	0.013	0.002	0.157	1.746	0.001	0.001
2/22/77	4.972	3.752	0.034	0.009	0.038	0.010	0.262	6.889	0.006	0.001
2/24/77	0.489	0.165	0.003	0.018	0.003	0.001	0.393	0.163	0.001	0.006
3/12/77	20.831	0.560	0.151	0.270	0.020	0.040	1.964	1.146	0.023	0.020
3/18/77	7.755	0.323	0.053	0.164	0.015	0.015	0.982	0.517	0.009	0.017
4/2/77	1.235	0.113	0.007	0.069	0.010	0.002	0.196	0.308	0.001	0.003
4/4/77	1.351	0.028	0.007	0.250	0.003	0.002	0.786	0.102	0.001	0.010
9/19/77	1.676	0.158	0.009	0.057	0.028	0.003	0.107	0.257	0.002	0.008
12/5/77	0.429	0.069	0.002	0.029	0.010	0.001	0.098	0.117	0.000	0.000
12/13/77	1.195	0.133	0.006	0.045	0.008	0.002	0.262	0.463	0.001	0.002
1/25/78	2.224	1.249	0.012	0.010	0.087	0.004	0.046	2.273	0.002	0.001
3/13/78	3.535	1.953	0.019	0.010	0.272	0.006	0.022	3.971	0.003	0.001
6/27/78	2.802	0.345	0.015	0.043	0.076	0.005	0.208	1.039	0.003	0.009
12/3/78	33.611	0.794	0.272	0.343	0.095	0.080	0.842	2.591	0.070	0.027
12/8/78	21.934	0.914	0.178	0.195	0.112	0.046	0.411	2.626	0.045	0.017
12/31/78	3.875	0.428	0.032	0.075	0.025	0.008	0.320	0.986	0.008	0.008
1/24/79	1.697	0.307	0.011	0.036	0.036	0.003	0.083	0.556	0.002	0.004
2/21/79	0.084	0.134	0.001	0.007	0.010	0.000	0.000	0.240	0.000	0.000
2/22/79	2.069	1.003	0.013	0.013	0.155	0.004	0.026	2.525	0.002	0.001
4/9/79	0.547	0.326	0.003	0.009	0.005	0.001	0.200	0.150	0.001	0.007
6/21/79	1.569	0.351	0.010	0.028	0.006	0.003	0.500	0.678	0.002	0.003
8/1/79	0.338	0.083	0.002	0.024	0.009	0.001	0.111	0.526	0.000	0.000
8/17/79	0.208	0.036	0.001	0.028	0.005	0.000	0.000	0.196	0.000	0.000
1/11/80	54.187	2.668	0.341	0.128	0.107	0.103	0.963	4.545	0.060	0.013
3/5/80	1.878	0.568	0.012	0.021	0.027	0.004	0.148	1.043	0.002	0.002
3/7/80	251.081	3.388	0.906	0.267	0.166	0.362	2.181	6.052	0.219	0.036

*Events with five or more discrete samples.

TABLE G-2. NUTRIENT FLUX DATA FOR WATERSHED 110 (SELECTED EVENTS)*

Gregorian date	Wheel sediment (kg/ha)	Total N Flux			Total P Flux			Extract K Flux		
		Soluble (kg/ha)	Sediment (kg/ha)	Sed-Sol ratio	Soluble (kg/ha)	Sediment (kg/ha)	Sed-Sol ratio	Soluble (kg/ha)	Sediment (kg/ha)	Sed-Sol ratio
4/2/77	1.219	0.029	0.005	0.172	0.003	0.002	0.667	0.048	0.001	0.021
9/19/77	66.002	0.594	0.228	0,384	0.109	0.084	0.771	0.723	0.035	0.048
10/1/77	2.861	0.120	0.012	0.100	0.031	0.004	0.129	0.196	0.002	0.010
11/17/77	0.731	0.013	0.003	0.231	0.003	0.001	0.333	0.036	0.000	0.000
12/5/77	5.332	0.263	0.023	0.087	0.030	0.007	0.226	0.326	0.003	0.009
12/14/77	5.065	0.402	0.021	0.052	0.019	0.006	0.316	0.598	0.003	0.005
3/13/78	1.383	0.463	0.004	0.009	0.043	0.002	0.047	0.682	0.001	0.001
5/13/78	3.761	0.054	0.011	0.204	0.030	0.004	0.019	0.201	0.004	0.020
9/14/78	5.016	0.287	0.015	0.052	0.036	0.005	0.125	0.551	0.005	0.009
10/12/78	16.393	0.432	0.048	0.111	0.084	0.018	0.225	0.871	0.016	0.018
12/3/78	3.499	0.106	0.015	0.142	0.033	0.004	0.121	0.340	0.003	0.009
12/8/78	2.201	0.117	0.009	0.077	0.025	0.003	0.120	0.213	0.002	0.009
2/23/79	0.128	0.209	0.001	0.005	0.012	0.000	0.000	0.277	0.000	0.000
2/25/79	0.320	0.157	0.001	0.006	0.017	0.000	0.000	0.268	0.000	0.000
7/22/79	14.902	0.411	0.061	0.148	0.060	0.019	0.317	1.974	0.012	0.006
7/25/79	1.010	0.117	0.004	0.034	0.013	0.001	0.077	0.441	0.001	0.002
8/1/79	9.413	0.688	0.038	0.055	0.093	0.012	0.129	2.334	0.008	0.003
8/18/79	9.630	10.996	0.039	0.004	0.404	0.012	0.030	7.113	0.008	0.001
9/14/79	5.373	1.408	0.022	0.016	0.111	0.007	0.063	1.542	0.004	0.003
9/27/79	0.725	0.109	0.003	0.028	0.013	0.001	0.077	0.334	0.001	0.003
2/21/80	0.008	0.111	0.000	0.000	0.006	0.000	0.000	0.182	0.000	0.000

*Events with five or more discrete samples.

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TABLE G-3. NUTRIENT FLUX DATA FOR WATERSHED 129 (SELECTED EVENTS)*

Gregorian rate	Wheel Sediment (kg/ha)	Total N Flux			Total P Flux			Extract K Flux		
		Soluble (kg/ha)	Sediment (kg/ha)	Sed-Sol ratio	Soluble (kg/ha)	Sediment (kg/ha)	Sed-Sol ratio	Soluble (kg/ha)	Sediment (kg/ha)	Sed-Sol ratio
4/28/77	8.312	0.133	0.049	0.368	0.023	0.011	0.478	0.970	0.018	0.019
7/4/77	9.553	0.286	0.050	0.175	0.081	0.010	0.123	1.235	0.008	0.006
7/16/77	69.810	0.704	0.425	0.604	0.141	0.092	0.643	2.851	0.079	0.028
7/21/77	2.656	0.094	0.013	0.138	0.029	0.004	0.138	0.504	0.002	0.004
9/19/77	6.839	0.210	0.029	0.138	0.133	0.007	0.053	1.301	0.004	0.003
9/26/77	0.324	0.035	0.001	0.029	0.014	0.000	0.000	0.187	0.000	0.000
10/1/77	5.792	0.262	0.026	0.099	0.178	0.006	0.034	2.126	0.003	0.001
11/7/77	6.006	0.277	0.058	0.209	0.103	0.013	0.125	2.660	0.014	0.005
11/30/77	16.937	0.624	0.142	0.228	0.087	0.035	0.402	3.210	0.060	0.019
12/5/77	302.385	1.858	2.299	1.237	0.168	0.431	2.565	3.628	0.300	0.083
12/13/77	211.517	1.383	1.394	1.008	0.038	0.301	7.921	4.598	0.212	0.046
1/7/78	67.154	0.819	0.370	0.452	0.125	0.101	0.808	4.862	0.116	0.024
3/13/78	12.808	0.611	0.105	0.172	0.085	0.025	0.298	2.143	0.011	0.005
3/26/78	24.817	0.136	0.128	0.941	0.007	0.037	5.286	0.120	0.019	0.158
4/18/78	23.994	0.578	0.162	0.280	0.016	0.036	2.250	0.652	0.028	0.043
4/20/78	44.651	0.465	0.240	0.516	0.041	0.063	1.537	0.779	0.056	0.072
5/8/78	11.706	0.188	0.061	0.324	0.018	0.016	0.889	0.706	0.013	0.018
8/5/78	2.206	0.111	0.015	0.135	0.108	0.004	0.037	1.428	0.002	0.001
8/30/78	0.512	0.059	0.003	0.051	0.055	0.001	0.018	0.571	0.000	0.000
9/14/78	8.253	0.513	0.056	0.109	0.456	0.012	0.026	4.842	0.008	0.002
11/17/78	6.886	0.166	0.048	0.289	0.041	0.013	0.317	0.781	0.013	0.017
12/3/78	250.274	1.894	1.866	0.985	0.247	0.451	1.826	5.285	0.320	0.061
12/8/78	28.516	0.483	0.404	0.836	0.098	0.106	1.082	1.892	0.100	0.053
12/31/78	62.125	0.427	0.447	1.047	0.031	0.102	3.290	0.739	0.078	0.106
2/25/79	78.396	1.640	0.957	0.584	0.331	0.218	0.659	3.232	0.169	0.052
4/2/79	14.277	0.204	0.102	0.500	0.019	0.025	1.316	0.385	0.021	0.055
4/4/79	113.417	1.000	0.908	0.908	0.057	0.219	3.842	1.518	0.188	0.124
4/9/79	139.418	1.022	1.547	1.514	0.086	0.317	3.686	2.499	0.338	0.135
4/12/79	17.198	0.344	0.120	0.349	0.009	0.029	3.222	0.300	0.023	0.077
4/13/79	131.341	0.365	0.815	2.233	0.019	0.234	12.316	0.740	0.159	0.215
5/12/79	206.085	1.132	0.709	0.626	0.046	0.202	4.391	2.084	0.171	0.082
5/29/79	23.663	0.081	0.077	0.951	0.009	0.020	2.222	0.169	0.013	0.077

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TABLE G-3. (continued)

Gregorian date	Wheel Sediment (kb/ha)	Total N Flux Soluble (kg/ha)	Total N Flux Sediment (kg/ha)	Total N Flux Sed-Sol ratio	Total P Flux Soluble (kg/ha)	Total P Flux Sediment (kg/ha)	Total P Flux Sed-Sol ratio	Extract K Flux Soluble (kg/ha)	Extract K Flux Sediment (kg/ha)	Extract K Flux Sed-Sol ratio
6/21/79	9.321	0.051	0.330	0.588	0.019	0.008	0.421	0.402	0.005	0.012
7/22/79	54.890	1.140	0.174	0.153	0.414	0.047	0.114	8.963	0.032	0.004
7/25/79	4.836	0.502	0.015	0.030	0.094	0.004	0.043	2.092	0.003	0.001
8/1/79	2.983	0.356	0.009	0.025	0.214	0.003	0.014	3.373	0.002	0.001
8/11/79	2.866	0.139	0.009	0.065	0.075	0.002	0.027	1.152	0.002	0.002
8/18/79	7.081	0.298	0.022	0.074	0.126	0.006	0.048	1.860	0.004	0.002
8/23/79	0.995	0.101	0.003	0.030	0.035	0.001	0.029	0.771	0.001	0.001
8/24/79	3.257	0.094	0.010	0.106	0.038	0.003	0.079	0.748	0.002	0.003
9/13/79	1.258	0.231	0.004	0.017	0.100	0.001	0.010	1.652	0.001	0.001
9/28/79	0.637	0.072	0.002	0.028	0.023	0.001	0.043	0.511	0.000	0.000
11/26/79	26.173	0.328	0.247	0.753	0.024	0.059	2.458	0.825	0.045	0.055
1/11/80	28.949	0.586	0.141	0.241	0.065	0.041	0.631	2.326	0.043	0.018
2/20/80	3.457	1.064	0.022	0.021	0.081	0.006	0.074	3.938	0.006	0.002
2/21/80	1.888	0.221	0.010	0.045	0.019	0.003	0.158	0.894	0.003	0.003
3/5/80	5.785	0.512	0.034	0.066	0.041	0.009	0.220	1.943	0.009	0.005
3/7/80	****	7.930	10.988	1.386	0.256	2.316	9.047	8.674	2.267	0.261

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*Events with five or more discrete samples.

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TABLE G-4. NUTRIENT CONCENTRATION DATA FOR WATERSHEDS 106, 110 and 129

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Date	Mean nutrient concentration on sediment (mg/kg sed)			Mean soluble nutrient concentrations (mg/l)		
	Total N	Total P	Ext K	Total N	Total P	Ext K
WATERSHED 106						
2/12/77	6867	1950	1135	14.4	0.35	45.3
2/22/77	6867	1950	1135	18.8	0.19	34.5
2/24/77	6867	1950	1135	9.9	0.20	9.7
3/12/77	7250	1938	1115	16.1	0.54	32.4
3/18/77	6858	1896	1179	18.5	0.84	29.4
4/2/77	5370	1679	989	5.2	0.47	14.2
4/477	5334	1679	972	3.7	0.41	13.4
7/4/77	5334	1679	972	7.3	1.34	13.4
9/19/77	5334	1679	972	5.9	1.04	9.7
12/5/77	5334	1679	972	2.2	0.30	3.6
12/13/77	5334	1679	972	1.7	0.10	5.9
1/25/78	5334	1679	972	8.6	0.60	15.6
3/13/78	5334	1679	972	12.7	1.75	25.5
6/27/78	5334	1679	972	4.4	0.95	13.1
12/3/78	8126	2375	2065	9.7	1.15	31.4
12/8/78	8126	2085	2065	10.0	1.22	28.5
12/31/78	8245	2073	2065	11.9	0.70	27.4
1/24/79	6302	1906	1101	3.4	0.41	6.3
2/21/79	6302	1906	1101	3.8	0.28	6.9
2/22/79	6302	1906	1101	3.8	0.57	9.4
4/9/79	6302	1906	1101	17.5	0.28	8.1
6/21/79	6302	1906	1101	37.4	0.68	72.2
8/1/79	6302	1906	1101	4.9	0.55	31.2
8/17/79	6302	1906	1101	2.8	0.41	15.4
1/11/80	6302	1906	1101	13.0	0.52	22.2
3/5/80	6302	1906	1101	11.2	0.53	20.5
3/7/80	3607	1441	873	15.8	0.77	28.1
WATERSHED 110						
4/2/77	4312	1354	1053	2.6	0.28	4.3
9/19/77	3453	1275	525	6.6	1.22	8.0
10/1/77	4236	1250	628	3.4	0.88	5.5
11/17/77	4236	1250	628	2.9	0.70	8.4
12/5/77	4236	1250	628	3.7	0.41	4.5
12/14/77	4236	1250	628	2.9	0.14	4.4
3/13/78	2953	1090	983	3.3	0.31	4.9
5/13/78	2953	1090	983	2.8	1.60	10.6
9/14/78	2953	1090	983	9.8	1.24	18.8
10/12/78	2953	1090	983	7.5	1.20	12.3
12/3/78	1270	797	1391	2.0	0.66	6.8
12/8/78	1270	797	1391	2.4	0.51	4.4
2/23/79	1270	797	1391	2.4	0.14	3.2

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Table G-4. (continued)

Date	Mean nutrient concentration on sediment (mg/kg sed)			Mean soluble nutrient concentrations (mg/l)		
	Total N	Total P	Ext K	Total N	Total P	Ext K
2/25/79	1270	797	1391	1.7	0.19	3.0
7/22/79	4088	1270	797	5.7	0.82	27.0
7/25/79	4088	1270	797	7.3	0.84	27.4
8/1/79	4088	1270	797	8.9	1.20	30.2
8/18/79	4088	1270	797	28.9	1.06	18.7
9/14/79	4088	1270	797	3.9	0.31	4.2
9/27/79	4088	1270	797	7.7	0.94	23.4
2/21/80	2706	833	920	4.9	0.30	8.2
WATERSHED 129						
4/28/77	5884	1310	2171	6.1	1.00	41.4
7/4/77	5279	1088	796	2.5	0.72	10.9
7/16/77	6083	1323	1131	7.0	1.40	28.1
7/21/77	4958	1475	792	3.3	1.00	17.5
9/19/77	4247	1115	662	2.5	1.54	15.4
9/26/77	4247	1115	662	5.0	1.93	26.6
10/1/77	4537	1042	500	2.1	1.45	17.4
11/7/77	9627	2098	2261	10.2	3.78	97.4
11/30/77	8357	2056	3554	12.4	1.70	63.3
12/5/77	7604	1427	993	13.4	1.21	26.0
12/13/77	6589	1421	1004	8.4	0.23	27.9
1/7/78	5513	1497	1732	12.3	1.80	75.5
3/13/78	8206	1959	840	6.9	0.96	24.2
3/26/78	5175	1479	757	15.7	0.81	13.9
4/18/78	6745	1534	1165	90.0	2.45	101.3
4/20/78	5368	1414	1256	25.8	2.28	43.1
5/8/78	5171	1344	1110	14.2	1.37	53.1
8/5/78	6862	1708	1120	2.0	1.99	26.3
8/30/78	6811	1490	975	3.1	1.76	26.4
9/14/78	6811	1490	975	3.2	2.82	29.9
11/17/78	7004	1823	1944	10.2	2.52	47.9
12/3/78	6541	1571	1106	12.0	1.54	37.2
12/8/78	6867	1808	1719	4.9	0.98	18.8
12/31/78	7202	1641	1253	19.9	1.47	34.4
2/25/79	6768	1545	1198	10.8	2.19	21.4
4/2/79	7125	1784	1454	20.8	1.95	39.0
4/4/79	7297	1764	1510	25.7	1.46	39.0
4/9/79	7679	1571	1676	17.7	1.48	43.2
4/12/79	6989	1707	1315	37.1	1.02	32.2
4/13/79	5223	1499	1018	13.4	0.71	27.2
5/12/79	3441	982	830	29.7	1.19	54.5
5/29/79	3249	826	558	6.3	0.67	13.0
6/21/79	3165	860	580	2.0	0.73	15.6
7/22/79	3165	860	580	8.6	3.12	67.4

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Table G-4. (continued)

Date	Mean nutrient concentration on sediment (mg/kg sed)			Mean soluble nutrient concentrations (mg/l)		
	Total N	Total P	Ext K	Total N	Total P	Ext K
7/25/79	3165	860	580	9.6	1.80	40.1
8/1/79	3165	860	580	3.4	2.03	31.9
8/11/79	3165	860	580	2.7	1.46	22.7
8/18/79	3165	860	580	3.7	1.56	23.1
8/23/79	3165	860	580	6.4	2.25	48.9
8/24/79	3165	860	580	4.6	1.87	36.9
9/13/79	3165	860	580	3.3	1.41	23.4
9/28/79	3165	860	580	2.8	0.91	19.7
11/26/79	9441	2246	1737	28.8	2.09	72.3
1/11/80	4897	1421	1508	14.0	1.57	55.9
2/20/80	6222	1604	1593	24.8	1.89	91.8
2/21/80	5290	1604	1593	15.8	1.37	63.9
3/5/80	5918	1604	1593	17.0	1.36	64.7
3/7/80	6844	1442	1412	46.0	1.49	50.3

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TABLE G-5. TOTAL NUTRIENT FLUX SUMMARY FOR WATERSHEDS 106, 110 AND 129*

Time period	Nitrogen flux (kg/ha)			Phosphorus flux (kg/ha)			Potassium flux (kg/ha)		
	Soluble	Sediment	Total	Soluble	Sediment	Total	Soluble	Sediment	Total
WATERSHED 106									
Growing Season 1977	0.407	0.018	0.425	0.0746	0.005	0.0796	0.707	0.003	0.710
Dormant Season 1977-78	4.151	0.045	4.196	0.4621	0.014	0.4761	7.789	0.007	7.796
Annual	4.558	0.063	4.621	0.5367	0.019	0.5557	8.496	0.010	8.506
Growing Season 1978	0.465	0.019	0.484	0.100	0.006	0.106	1.579	0.003	1.582
Dormant Season 1978-79	6.439	0.662	7.101	0.732	0.186	0.918	14.142	0.155	14.297
Annual	6.904	0.681	7.585	0.832	0.192	1.024	15,721	0.158	15.679
Growing Season 1979	5.864	0.277	6.141	0.330	0.083	0.413	8.008	0.047	8.055
Dormant Season 1979-80	9.175	1.318	10.493	0.445	0.487	0.932	16.683	0.291	16,974
Annual	15.039	1.595	16.634	0.775	0.570	1.345	24.691	0.338	25.029
WATERSHED 110									
Growing Season 1977	1.031	0.387	1.418	0.168	0.135	0.303	1.442	0.067	1.509
Dormant Season 1977-78	1.355	0.063	1.418	0.123	0.019	0.142	2.038	0.009	2.047
Annual	2.386	0.450	2.836	0.291	0.154	0.445	3.480	0.076	3.556
Growing Season 1978	1.340	0.095	1.435	0.292	0.035	0.327	3.519	0.031	3.550
Dormant Season 1978-79	0.910	0.031	0.941	0.105	0.008	0.113	1.422	0.005	1.427
Annual	2.250	0.126	2.376	0.397	0.043	0.440	4.941	0.036	4.977

(continued)

TABLE G-5. (continued)

Time period	Nitrogen flux (kg/ha)			Phosphorus flux (kg/ha)			Potassium flux (kg/ha)		
	Soluble	Sediment	Rotal	Soluble	Sediment	Total	Soluble	Sediment	Total
Growing Season 1979	14.057	0.173	14.230	0.720	0.053	0.773	14.411	0.035	14.446
Dormant Season 1979-80 Annual	1.231 15.288	0.190 0.363	1.421 15.651	0.070 0.790	0.058 0.111	0.128 0.901	1.516 15.927	0.060 0.095	1.576 16.022
WATERSHED 129									
Growing Season 1977	2.187	0.798	2.985	0.745	0.174	0.919	11.278	0.140	11.418
Dormant Season 1977-78 Annual	9.297 11,484	6.574 7.372	15.871 18.856	1.137 1.882	1.420 1.594	2.557 3.476	31.627 42.905	1.163 1.303	32.790 44.208
Growing Season 1978	5.288	3.299	8.587	1.551	0.781	2.332	21.899	0.577	22.476
Dormant Sea-Season 1978-79 Annual	9.155 14.443	7.373 10.672	16.528 25.115	1.368 2.919	1.750 2.531	3.118 5.450	23.215 45.114	1.436 2.013	24.651 47.127
Growing Season 1979	5.584	1.093	6.677	1.683	0.305	1.988	30.329	0.241	30.570
Dormant Season 1979-80 Annual	10.701 16.285	11.453 12.546	22.154 28.831	0.495 2.178	2.436 2.741	2.931 4.919	19.038 49.367	2.374 2.615	21.412 51.982

*All runoff events were used to determine these flux values.

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APPENDIX H

RUNOFF, CONCENTRATION AND FLUX DATA FOR CONTROL WATERSHED (WS 172)

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TABLE H-1. TABULATION OF RUNOFF, AVERAGE MONTHLY NUTRIENT CONCENTRATION AND NUTRIENT FLUX FOR CONTROL WATERSHED (WS 172)

Period	Runoff (mm)	Total N (mg/ℓ)	Total N (kg/ha)	Total P (mg/ℓ)	Total P (kg/ha)	K (mg/ℓ)	K (kg/ha)	TOC (mg/ℓ)	TOC (kg/ha)
5/77	3.40	0.600	0.200	NA	NA	NA	NA	NA	NA
6/77	0.0	--	0.00	--	0.00	--	0.000	NA	0.000
7/77	2.20	1.000	0.024	0.030	0.001	NA	NA	NA	NA
8/77	0.0	--	0.000	--	0.000	--	0.000	--	0.000
9/77	6.71	2.458	0.165	0.010	0.001	NA	NA	NA	NA
10/77	13.04	3.200	0.417	0.010	0.001	NA	NA	NA	NA
GS	24.35	--	0.806	--	0.003	--	--	--	--
11/77	27.41	0.586	0.161	0.010	0.003	NA	NA	NA	NA
12/77	91.31	NA	NA	0.010	NA	NA	NA	NA	NA
1/78	23.93	0.817	0.015	0.010	0.002	NA	NA	NA	NA
2/78	0.0	--	0.000	--	0.000	--	0.000	NA	NA
3/78	85.88	1.600	1.374	0.010	0.009	NA	NA	NA	NA
4/78	17.04	1.351	0.130	--	0.188	0.870	0.148	8.079	1.376
DS	245.57	--	1.860	--	0.202	--	--	--	--
5/78	18.21	1.322	0.241	0.069	0.013	1.572	0.286	10.566	1.924
6/78	20.88	1.412	0.295	0.110	0.023	2.200	0.459	36.000	7.518
7/78	0.06	1.700	0.001	0.110	0.0	2.200	0.001	36.000	0.021
8/78	0.09	1.700	0.002	0.110	0.0	2.200	0.002	36.000	0.034
9/78	1.73	2.700	0.046	0.070	0.001	2.800	0.048	27.000	0.466
10/78	2.20	3.194	0.070	0.140	0.003	2.800	0.062	24.000	0.527
GS	43.17	--	0.655	--	0.040	--	0.858	--	10.490
11/78	0.00	--	0.00	--	0.000	--	0.000	--	0.000
12/78	65.66	2.243	1.372	0.022	0.014	1.860	1.221	8.815	5.788
1/79	2.74	1.300	0.036	0.030	0.001	1.500	0.041	5.000	0.137
2/79	105.03	1.600	1.680	0.010	0.011	1.300	1.365	5.000	5.251
3/79	2.06	1.100	0.023	0.010	0.000	1.600	0.033	10.000	0.206
4/79	66.27	1.109	0.735	0.014	0.009	1.200	0.795	5.717	3.789
DS	241.76	--	3.846	--	0.035	--	3.455	--	15.171

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TABLE H-1. (continued)

Period	Runoff (mm)	Total N (mg/ℓ)	Total N (kg/ha)	Total P (mg/ℓ)	Total P Kkg/ha)	K (mg/ℓ)	K (kg/ha)	TOC (mg/ℓ)	TOC (1g/ha)
5/79	7.88	1.000	0.079	0.013	0.001	1.557	0.123	10.618	0.837
6/79	0.44	1.000	0.005	0.030	0.000	1.600	0.007	11.000	0.049
7/79	0.86	2.300	0.019	0.054	0.000	2.988	0.026	35.765	0.309
8/79	10.14	4.748	0.481	0.025	0.003	2.235	0.227	20.812	2.110
9/79	52.47	6.800	2.568	0.030	0.016	2.700	1.417	67.000	35.157
10/79	0.0	--	0.00	--	0.000	--	0.000	--	0.000
GS	61.79	--	3.152	--	0.020	--	1.800	--	38.462
11/79	9.89	1.280	0.116	0.042	0.004	1.960	0.194	4.400	0.435
12/79	12.45	1.200	0.137	0.050	0.006	1.900	0.237	4.000	0.498
1/80	42.18	1.200	0.464	0.050	0.021	1.900	0.801	4.000	1.687
2/80	0.00	--	0.000	--	0.000	--	0.000	--	0.000
3/80	55.46	4.200	2.329	0.040	0.022	2.300	1.276	10.887	6.038
4/80	34.66	2.000	0.659	0.020	0.007	1.300	0.451	9.000	3.120
DS	154.64	--	3.705	--	0.060	--	2.959	--	11.778

NA = Data not available

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APPENDIX I

SUMMARY OF TOC, COD AND BOD DATA FOR WS 106, WS 110 AND WS 129

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TABLE I-1. SUMMARY OF RUNOFF, MEAN CONCENTRATION AND FLUX FOR TOC, COD AND BOD FOR WS 106

Period*	Runoff	Mean ($\bar{x}$) concentration			Flux		Runoff events
		TOC	COD	BOD#	TOC	COD	
	- mm -	- - - - - - - mg/ℓ- - - - - - - -			- - -kg/ha- - -		(number)
GS 77	8.467	23	68	7	2.8	2.7	14
DS 77-78	47.498	36	79	25	17.0	50.1	33
Water Year	55.965	32	76	16	19.8	52.8	47
GS 78	10.514	39	64	26	4.5	4.3	36
DS 78-79	70.704	40	82	11	24.6	71.8	25
Water Year	81.218	39	71	20	29.1	76.1	61
GS 79	53.681	34	70	11	3.3	17.6	18
DS 79-80**	67.430	36	122	23	34.7	106.3	12
Water Year**		35	91	16			30

*GS = growing season (May-Oct). DS = dormant season (Nov-Apr).

#BOD analyses were not conducted on all runoff samples.

**Sampling was stopped on 3/15/80, 45 days short of a full dormant season or water year.

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TABLE I-2. SUMMARY OF RUNOFF, MEAN CONCENTRATION AND FLUX FOR TOC, COD AND BOD FOR WS 110.

Period*	Runoff	Mean ($\bar{x}$) concentration			Flux		Runoff events
		TOC	COD	BOD#	TOC	COD	
	- mm -	- - - - - - - -mg/ℓ - - - - - - -			- - -kg/ha- - -		(number)
DS 76-77**	3.9	22	69	--	0.8	--	9
GS 77	14.713	69	135	7	4.3	13.1	15
DS 77-78	42.330	16	33	8	6.2	10.5	15
Water year	57.043	43	82	8	10.5	23.6	30
GS 78	21.001	43	82	19	7.7	16.4	19
DS 78-79	33.072	17	40	7	4.6	10.1	16
Water year	54.073	31	62	13	12.3	26.5	35
GS 79	96.009	35	76	20	23.1	45.2	12
DS 79-80**	17.023	25	77	12	3.7	10.8	9
Water year##		31	76	17			21

*GS = growing season (May-Oct). DS = dormant season (Nov-Apr).

#BOD analyses were not conducted on all runoff samples.

**Sampling commenced on 2/22/77. COD analyses commenced on 4/2/77.

##Sampling was stopped on 3/15/80, 45 days short of a fall dormant season or water year.

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TABLE I-3. SUMMARY OF RUNOFF, MEAN CONCENTRATION AND FLUX FOR TOC, COD AND BOD FOR WS 129

Period*	Runoff	Mean ($\bar{x}$) concentration			Flux		Runoff events
		TOC	COD	BOD#	TOC	COD	
	- mm-	- - - - - - - -mg/ℓ - - - - - - - -			- - -kg/ha - - -		(number)
DS 76-77**	55.320	83	23.8	--	58.7	--	22
GS 77	56.984	39	76	7	16.3	42.1	44
DS 77-78	80.965	65	287	60	77.5	212.9	39
Water year	137.949	52	175	54	93.8	254.0	83
GS 78	99.429	73	140	24	49.6	123.5	44
DS 78-79	76.659	106	338	36	87.3	254.8	35
Water year	176.088	87	228	29	136.9	378.3	79
GS 79	114.443	50	137	22	36.0	101.6	26
DS 79-80	32.010	93	287	40	67.0	192.6	12
Water year##		64	184	27			38

*GS = growing season (May-Oct). DS = dormant season (Nov-Apr).

#BOD analysis was not conducted on all runoff samples.

**Sampling commenced on 12/7/76. COD analyses commenced on 4/2/77.

##Sampling was stopped on 3/15/80, 45 days short of a full dormant season or water year.

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